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By J. M. LAMONT
Marine Laboratory, Aberdeen
February, 1967

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Plaice Investigations in Scottish Waters
2. Age-Composition and Growth

INTRODUCTION

In an earlier paper (Lamont, 1964) the author indicated the importance of the plaice, *Pleuronectes platessa* , in Scottish fisheries and outlined the various changes in Scottish fishery legislation and in fishing practice om 1910 to 1952. Particular attention was given to the effect of these developments on the size-composition the plaice stocks of the principal Scottish plaice area, the east coast, during these years. The analysis showed at, following the introduction of the seine-net method of fishing in 1921, the plaice stocks in all regions of the ea were characterised by a steady reduction, temporarily arrested during the two war periods in some regions, the average size of marketable-sized fish.

The present paper is concerned with the corresponding changes in the age-composition and the fluctuation year-class abundance of the stocks from 1920, when systematic age-determination was initiated. As might expected from the marked change in the size of the fish demonstrated in the previous paper, the age-mposition changed in a similar manner. Because of this the measure of the decline in age-structure is only iefly indicated, precedence being given to an analysis of the fluctuations in brood strengths of the various aice populations and to their inter-relationships and causes. In addition, the age-determination of plaice ocks off the north and west coasts and the Orkney and Shetland Islands are also considered both individually d in relation to the main, more intensively sampled, east coast communities.

The validity of the method of age-determination of plaice from the otoliths, so far as its application to ottish plaice is concerned, is discussed in the Appendix.

Finally, the important question of the growth of the plaice is examined and regional growth-rate values mpared.

Full details of the grounds surveyed and the vessels employed in the collection of the material were given the previous paper, but for convenience of reference the east coast regions are reproduced in Figure 1. ne data comprised two overlapping series:—

Series 1: from two larger vessels, *Goldseeker* and *Explorer*, operating in depths of 6–50 fm, during the periods 1920–39 and 1946–52.

Series 2: from two smaller vessels, *Enid* and *Kathleen*, the former operating in 2–10 fm during the years 1931–35, and the latter in 2–25 fm in 1937–39 and 1964–52.

The gear used throughout was a small otter trawl with small-mesh cover over the cod-end.

The ensuing analysis is based on the examination of approximately 300,000 otoliths or ear-bones. Age s been indicated by the recognised formula:— under 1 year old=group O; between 1 and 2 years old=group between 2 and 3 years old=group II, etc., with a fixed 'birthday' on 1st April.

Although it would be desirable to evaluate age-composition and year-class abundance on an absolute, antitative basis, this is not possible in view of the varying circumstances of the sampling. In consequence, e percentage method has been applied. It is recognised that this method does not show the true abundance a year-class but only its proportion to the other year-classes constituting the population and can be indicative ly of the relative strengths of the component broods. Whether the abundance of these broods is estimated atively or absolutely it would also be desirable to use the same age-groups (preferably the youngest, most ly represented group and least affected by fishing mortality). Owing, however, to the varying factors referred and to the absence of observations during the two war periods, different age-groups, not always the youngest, e necessarily used as indices of brood strength. Where possible, however, the youngest, most fully represented e-group is used. Towards this end, with certain exceptions, only the data from shallower water in the two ies have been used, while from 1931 the smaller ships' observations, also with certain exceptions, have been

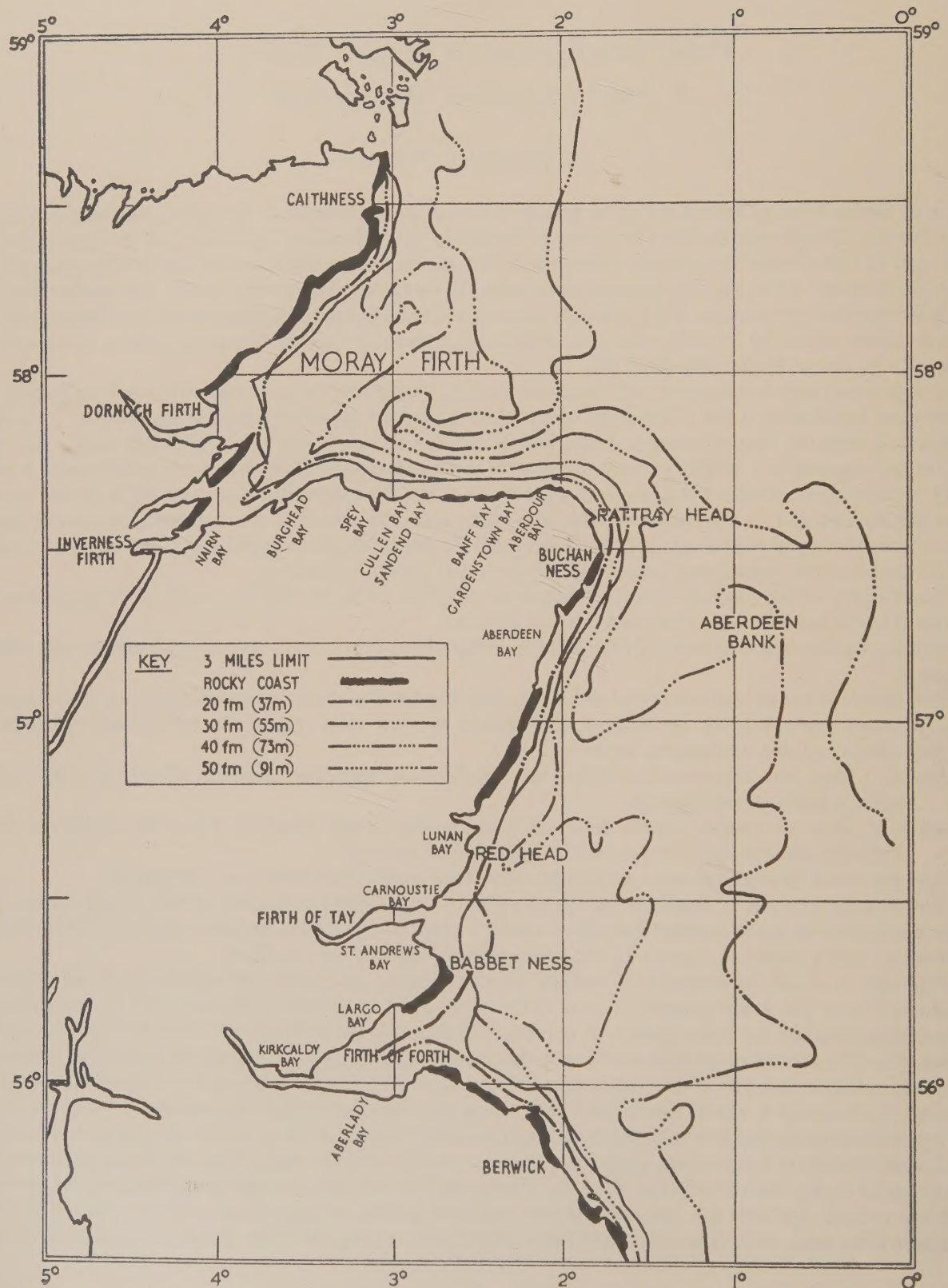

Fig. 1 Scottish east coast fishery regions.

used in preference to the larger ships' material. The exceptions are the years immediately after the First and Second World Wars, 1920–22 and 1946–52 (when, in the absence of observations on the youngest stages of broods spawned during the war periods, assessment of these broods is based on older fish from deeper water) and in 1936 (when neither of the two smaller vessels was in commission and surveys were carried out by the larger vessel *Explorer*). Also, in order to maintain uniform comparison between regions, in the surveys of the small ships *Enid* and *Kathleen* (Series 2) begun in 1931 only the data from such depth zones as were common to both vessels (the shallower zones 2–10 fm) have been used.

In the assessments the O-group is disregarded as these youngest fish were almost completely unrepresented in the early surveys by the larger vessels, and, although forming a significant component of the populations sampled in the later investigations carried out closer inshore by *Enid* and *Kathleen*, proved too sporadic in their occurence and therefore statistically unreliable for inclusion in total population age-assessment or evaluation of year-class abundance. Groups I and II accordingly form the basis of the estimations, the measure of their abundance being expressed as follows:— 60%=very good, 40–60%=good, 20–40%=moderate or intermediate, and 20% or less=poor or very poor. In addition, secondary modes of these year-classes at ages 3 and 4, where they occur, are used to support the primary values. In some cases older fish are also used (for example in the two war periods) but in these instances it has been necessary to resort to interpolations and assumptions. Very old fish in the east coast samplings are combined in the tables and figures as group X and older. In the other areas examined representation beyond age-group VII is small and these have been combined as group VII+.

AGE-COMPOSITION OF STOCKS

East Coast Regions

Brood fluctuation

Appendix Tables 1–10 and Figure 2 give the annual age-composition from 1920 to 1952 of the plaice stocks in each of the four east coast regions, (1) the Moray Firth, (2) Rattray Head to Red Head, (3) Red Head to Babbet Ness and (4) the Firth of Forth.

It is necessary to examine in detail the corresponding changes in age-structure which accompanied those in size outlined in the previous paper. Like the changes in size, they were considerable except in the more or less static, small-plaice region, Red Head–Babbet Ness, where age-composition remained fairly constant, the oldest group in this region rarely exceeding four years of age during the whole period under review. In the other three regions the salient features of age-structure changes are similar except in the time factor. In all three regions fish of 10 to at least 20 years of age were represented on these grounds until the first stages of expansion of the seine-net fishery in 1921–24. Thereafter, the numbers of old fish declined still further, the maximum age falling by 1930 to below 10 years and by 1939 to below six years, except in the Firth of Forth where for a time the older plaice survived rather better than elsewhere. A substantial recovery in the older age components is evident after World War II, even to the reappearance of group X and older fish on the outer Moray Firth grounds up to 1949, and in the Rattray Head–Red Head region to 1952, but otherwise the age-maxima declined to groups VI or VII by 1952.

Excluding the very old broods of 1900–1910, the year-classes whose strengths can be estimated are as follows in the four east coast regions:—

Moray Firth: 1911–51=41 (Appendix Tables 1–3)

Rattray Head–Red Head: 1918–38; 1946–51=27 (Appendix Tables 4–6)

Red Head–Babbet Ness: 1921–38; 1945–51=25 (Appendix Tables 7–8)

Firth of Forth: 1911–51 except 1939=40 (Appendix Tables 9–10)

Employing the methods described on page 5, the estimated strengths of these are shown in chronological succession (Table I), by abundance values (Table II), and in symbol form (Table III); in Table III the abundance classifications have been combined into three main categories, good–very good (+), intermediate or moderate (I) and poor–very poor (O).

Wide variations in the degree of recruitment occurred in the different regions. Of the five classifications, very good productive years occurred in from 10 to 40% of the total number of years, good years in from 8 to

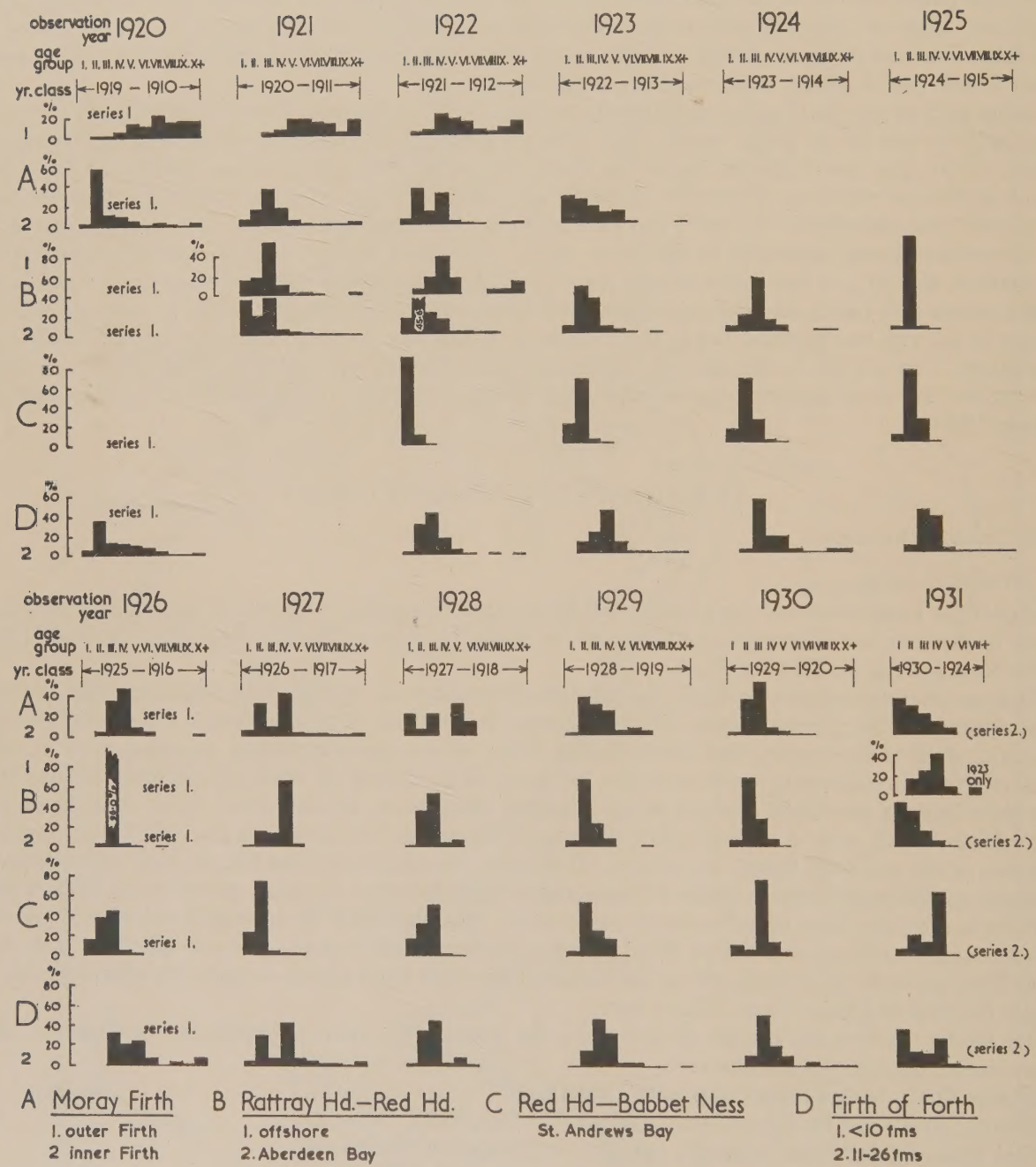

Fig. 2a Age-composition of plaice stocks on the Scottish east coast, 1920–1931.

Fig. 2b Age-composition of plaice stocks on the Scottish east coast, 1932–1952.

TABLE I

PLAICE BROOD STRENGTHS IN CHRONOLOGICAL ORDER

Year-Class	Moray Firth	Rattray Hd–Red Hd (Aberdeen Bay)	Red Hd–Babbet Ness (St Andrews Bay)	Firth of Forth
1900–1910	Not assessable			
1911	probably G	insuffiicent representation to be accurately assessable	no observations	no apparent fluctuations: all assessed as at least moderate
1912	< 1911: probably M			
1913	probably G			
1914	< 1913: probably M			
1915	< 1913: probably M			
1916	< 1913: probably M			
1917	probably M			
1918	VG	G		at least moderate
1919	P	P		G
1920	M	G	?	M
1921	M	G	VG	G
1922	VG	P	VG	G
1923	VG	VG	VG	M
1924	VP	VP	P	VP
1925	M	G	VG	G
1926	M	M	M	G
1927	G	VG	VG	VG
1928	M	G	VP	P
1929	M	M	M	M
1930	M	M	M	M
1931	VG	VG	VG	VG
1932	VP	VP	M	G
1933	VG	VG	VG	G
1934	VG	VG	G	G
1935	G	VG	VG	VG
1936	M	P	M	M
1937	G	VG	P	M
1938	P	M	VG	G
1939	< 1938: probably P	insufficient data for assessment: 1942 probably better than 1943 and 1944	No observations on young fish in these years or on older fish in years after World War II	no observations insufficient representation probably M or G: 1943 better than 1944
1940	no apparent fluctuations probably all M to G			
1941				
1942				
1943				
1944				
1945			G	M
1946	G	VG	VG	VG
1947	M	M	P	P
1948	G	VG	P	M
1949	M	VP	M	G
1950	M	VG	M	G
1951	P	M	M	P

Key
VG = Very Good
G = Good
M = Moderate
P = Poor

TABLE II

ASSESSMENT OF PLAICE BROODS BY ABUNDANCE

			No.		%	
	Moray Firth					
Very Good	1918, '22 '23 '31 '33 '34	=	6	13	14·6	31·6
Good	1911, '13 '27 '35 '37 '46 '48	=	7		17·0	
Moderate or Intermediate	1912, '14–'17 '20 '21 '25 '26 '28–'30 '36 '40–'45 '47 '49 '50	=	22	22	53·7	53·7
Poor	1919, '38 '39 '51	=	4	6	9·8	14·7
Very Poor	1924, '32	=	2		4·9	
		Total =	41			
	Rattray Head–Red Head					
Very Good	1923, '27 '31 '33 '34 '35 '37 '46 '48 '50	=	10	15	37·0	55·5
Good	1918, '20 '21 '25 '28	=	5		18·5	
Moderate or Intermediate	1926, '29 '30 '38 '47 '51	=	6	6	22·2	22·2
Poor	1919, '22 '36	=	3	6	11·1	22·2
Very Poor	1924, '32 '49	=	3		11·1	
	not known 1911–17; 1939, 1940–45	Total =	27			
	Red Head–Babbet Ness					
Very Good	1921, '22 '23 '25 '27 '31 '33 '35 '38 '46	=	10	12	40·0	48·0
Good	1934, '45	=	2		8·0	
Moderate or Intermediate	1926, '29 '30 '32 '36 '49 '50 '51	=	8	8	32·0	32·0
Poor	1924, '37 '47 '48	=	4	5	16·0	20·0
Very Poor	1928	=	1		4·0	
	not known 1911–20; 1939–44	Total =	25			
	Firth of Forth					
Very Good	1927, '31 '35 '46	=	4	15	10·0	37·5
Good	1919, '21 '22 '25 '26 '32 '33 '34 '38 '49 '50	=	11		27·5	
Moderate or Intermediate	1911–'17 '18 '20 '23 '29 '30 '36 '37 '40–45 '48	=	21	21	52·5	52·5
Poor	1928, '47 '51	=	3	4	7·5	10·0
Very Poor	1924	=	1		2·5	
	not known 1939	Total =	40			

TABLE III

ASSESSMENT OF PLAICE BROOD STRENGTHS SHOWN SYMBOLICALLY

Brood	Moray Firth	Rattray Hd –Red Hd	Red Hd– Babbet Ness	Firth of Forth
1911	+	(I)	—	(I)
1912	I	(I)	—	(I)
1913	+	(I)	—	(I)
1914	I	(I)	—	(I)
1915	I	(I)	—	(I)
1916	I	(I)	—	(I)
1917	I	(I)	—	(I)
1918	+	+	—	I
1919	o	o	—	+
1920	I	+	—	I
1921	I	+	+	+
1922	+	o	+	+
1923	+	+	+	I
1924	o	o	o	o
1925	I	+	+	+
1926	I	I	I	+
1927	+	+	+	+
1928	I	+	o	o
1929	I	I	I	I
1930	I	I	I	I
1931	+	+	+	+
1932	o	o	I	+
1933	+	+	+	+
1934	+	+	+	+
1935	+	+	+	+
1936	I	o	I	I
1937	+	+	o	I
1938	o	I	+	+
1939	o	—	—	—
1940	(I)	—	—	(I)
1941	(I)	—	—	(I)
1942	(I)	—	—	(I)
1943	(I)	—	—	(I)
1944	(I)	—	—	(I)
1945	(I)	—	+	I
1946	+	+	+	+
1947	I	I	o	o
1948	+	+	o	I
1949	I	o	I	+
1950	I	+	I	+
1951	o	I	I	o

Key

\+ = Good—Very Good
I = Intermediate
o = Poor—Very Poor
— = Insufficient or no records
(I) = Largely assumed

27%, years of intermediate or moderate strength in from 22·2 to 53·7% and unsuccessful spawnings, poor and very poor, in from 7·5 to 16% and from 2·5 to 11·1% respectively (Table II). All the regions are more or less fortunate as regards the incidence of successful broods while years of unsuccessful survival are in a minority in each area.

The VG classification includes particularly prolific recruitment years which occurred in the different regions. These may be recognised by the extension of their representation at significant levels beyond group III. Based on the arbitrary value of 40% at group IV, these exceptionally productive years occurred only in the following few instances:— in the Moray Firth in 1922 and 1923, in the Rattray Head region in 1923, the Red Head-Babbet Ness region in 1927 and 1946, and in the Firth of Forth in 1946.

Wide variations in recruitment thus occurred both annually and regionally during the years under review. It is necessary to ascertain if any decline occurred in recruitment during the development of Danish seine-net fishing and to what extent brood fluctuations may have been associated with, if not responsible for, any such

TABLE IV

PERIODIC VARIATION IN PLAICE BROOD STRENGTHS

Broods	1921–26	1927–32	1933–38	1946–51
		Moray Firth		
Good–very good	2	2	4	2
Intermediate	3	3	1	3
Poor–very poor	1	1	1	1
		Rattray Head–Red Head		
Good–very good	3	3	4	3
Intermediate	1	2	1	2
Poor–very poor	2	1	1	1
		Red Head–Babbet Ness		
Good–very good	4	2	4	1
Intermediate	1	3	1	3
Poor–very poor	1	1	1	2
		Firth of Forth		
Good–very good	4	3	4	3
Intermediate	1	2	2	1
Poor–very poor	1	1	0	2

decline. In other words, did the varying rates of thinning of the adult stock by fishing have some effect on brood production in the different regions, or were natural causes either wholly or partially responsible for the brood fluctuations? It is not possible in view of the limits within which investigations were carried out to answer these questions satisfactorily. It is possible, however, to indicate the main features of the effect of fishing on brood production and the extent of brood variance or inter-relationship between the regions, if not to relate them.

For these purposes only those broods for which strength data are simultaneously available for all regions and defined with greatest precision have been utilised. These are the eighteen broods 1921–38 and the six broods 1946–51.

Annual variation

For comparative purposes the twenty-four broods being considered have been divided into four equal periods of six broods—1921–26, 1927–32, 1933–38, 1946–51. On the basis of the strength values in Table III, the numbers of broods in the three main strength classifications, good–very good, intermediate, poor–very poor, in the four regions are shown in Table IV.

It would appear that, despite the considerable reduction in the numbers of adult plaice between the two wars and after World War II in the Moray Firth and Rattray Head regions (Lamont, 1964), recruitment in these areas during the period under review was maintained at replenishment levels sufficient to ensure that

TABLE V

PLAICE BROOD STRENGTHS
REGIONAL COINCIDENT YEARS: CONDITIONS IN NON-COINCIDENT REGION(S)

All Regions

Positive :	1927, 1931, 1933, 1934, 1935, 1946	
Intermediate:	1929, 1930	
Negative :	1924	

Moray Firth : Rattray Head–Red Head : Red Head–Babbet Ness

Positive :	1923	(Firth of Forth, intermediate)
Intermediate:	1926	(Firth of Forth, positive)

Moray Firth : Rattray Head–Red Head

Positive :	1937	(Red Head–Babbet Ness, negative; Firth of Forth, intermediate)
	1948	(Red Head–Babbet Ness, negative; Firth of Forth, intermediate)
Intermediate:	1947	(Red Head–Babbet Ness and Firth of Forth, both negative)
Negative :	1932	(Red Head–Babbet Ness, intermediate; Firth of Forth, positive)

Rattray Head–Red Head : Red Head–Babbet Ness : Firth of Forth

Positive :	1921, 1925	(Moray Firth, both years intermediate)

Rattray Head–Red Head : Red Head–Babbet Ness

Intermediate:	1951	(both Moray Firth and Firth of Forth, negative)

Red Head–Babbet Ness : Firth of Forth

Positive :	1922	(Moray Firth, positive: Rattray Head–Red Head, negative)
	1938	(Moray Firth, negative: Rattray Head–Red Head, intermediate)
Intermediate:	1936	(Moray Firth, intermediate: Rattray Head–Red Head, intermediate)
Negative :	1928	(Moray Firth, intermediate: Rattray Head–Red Head, positive)
	1947	(Moray Firth, intermediate: Rattray Head–Red Head, intermediate)

Variable (no two contiguous regions coincident) 1949, 1950.

TABLE VI

PLAICE BROOD STRENGTH: REGIONAL RELATIONSHIPS

Moray Firth and Rattray Head–Red Head

Positive :	1923, 1927, 1931, 1933, 1934, 1935, 1937, 1946, 1948	= 9	15
Intermediate:	1926, 1929, 1930, 1947	= 4	
Negative :	1924, 1932	= 2	

Moray Firth : Rattray Head–Red Head : Red Head–Babbet Ness

Positive :	1923, 1927, 1931, 1933, 1934, 1935, 1946	= 7	11
Intermediate:	1926, 1929, 1930	= 3	
Negative :	1924	= 1	

Moray Firth : Rattray Head–Red Head : Red Head–Babbet Ness and Firth of Forth (i.e. whole coast)

Positive :	1927, 1931, 1933, 1934, 1935, 1946	= 6	9
Intermediate:	1929, 1930	= 2	
Negative :	1924	= 1	

Rattray Head–Red Head : Red Head–Babbet Ness

Positive :	1921, 1925	= 2	3
Intermediate:	1951	= 1	

Rattray Head–Red Head : Red Head–Babbet Ness : Firth of Forth

Positive :	1921, 1925	= 2

Red Head–Babbet Ness : Firth of Forth

Positive :	1922, 1938	= 2	5
Intermediate:	1936	= 1	
Negative :	1928, 1947	= 2	

he stock was not endangered. On the other hand, in the two regions to the south (Red Head–Babbet Ness nd the Firth of Forth) the results suggest some decline in recruitment in the years 1946–51. It was also shown hat in the Firth of Forth no significant decline in the adult population occurred until these years. It would seem, therefore, that although in the Moray Firth and Rattray Head–Red Head regions thinning of the adult stock had no noticeable effect on brood production, this cannot be excluded as a possible cause of poor recruitment in the Firth of Forth, though the effects of fishing outside as well as inside its boundaries must also be taken into account. It must not be overlooked that natural causes may also have had some effect but, as already stated, it is not possible either to differentiate between or to correlate the effects of fishing and those caused

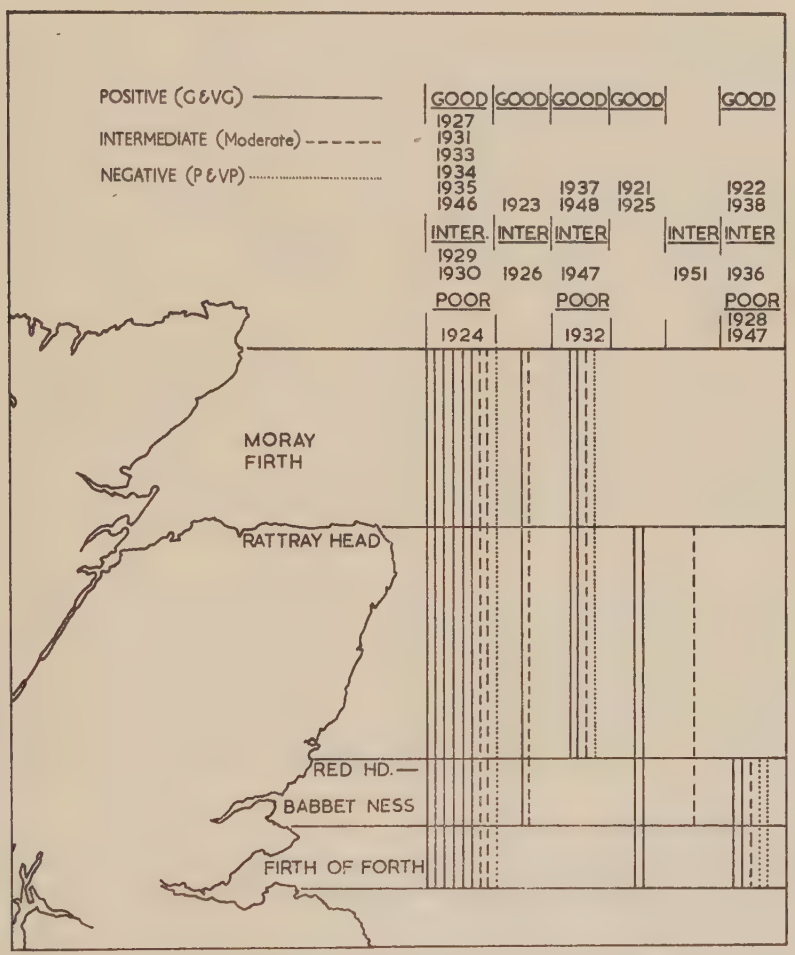

Fig. 3 Plaice brood 'strengths' illustrating regional coincident years.

naturally. The same circumstances would appear to explain the simultaneous reduction in brood strengths in he adjacent Red Head–Babbet Ness region, except that in this area any effect of fishing would be attributable n greater measure to the exploitation of the adult stock outside its boundaries. Here again the relative contributions of fishing and natural causes cannot be assessed. As will be shown later, however, the two areas are closely associated biologically in recruitment to the stocks and it is, therefore, possible that although fishing played some part in the decline natural causes played the greater part.

Regional variation (Tables III, V, VI: Fig. 3)

Of the twenty-four broods from 1921 to 1938 and from 1946 to 1951, nine were coincident throughout ll four regions (6 positive—1927, 1931, 1933, 1934, 1935, 1946; 2 intermediate—1929, 1930; 1 negative—924). In addition two were coincident in the three regions Moray Firth, Rattray Head–Red Head and Red

Head–Babbet Ness (positive 1—1923; intermediate 1—1926); four in the Moray Firth and Rattray Head–Red Head region (positive 2—1937, 1948; intermediate 1—1947; negative 1—1932); one of an intermediate nature (1951) in the regions Rattray Head–Red Head and Red Head–Babbet Ness; two positive years (1921, 1925) covering all regions except the Moray Firth; while five coincident years concerned the Red Head–Babbet Ness region and Firth of Forth only (positive 2—1922, 1938; intermediate 1—1936; negative 2—1938, 1947). Two broods (1949, 1950) were variable, showing no pattern of relationship with adjacent regions.

These results suggest certain inter-relationships between the regions in respect of settlement of fry. The relationship is not completely uniform. The extent of these inter-relationships—both of the coast as a whole and more locally—is shown in Table V and Figure 3 where coincident years are shown integrated by adjacent regions. Three main associated groups emerge, one concerned with the Moray Firth in relation to the rest of the coast, a second group, unconnected with the Moray Firth, concerned with the region Rattray Head–Red Head and southwards and a third group, also unassociated with the Moray Firth, in which coincident years are confined to the Red Head–Babbet Ness region and the Firth of Forth only. Thus the Moray Firth was associated with the adjacent region Rattray Head–Red Head on fifteen occasions, with that area and its neighbouring region Red Head–Babbet Ness on eleven occasions and with these and the Firth of Forth (i.e. the whole coast as referred to above) on nine occasions. In the second group, the Rattray Head–Red Head region was associated with its southerly neighbour Red Head–Babbet Ness on three occasions and with the Firth of Forth twice, while in the third group, concerned with region Red Head–Babbet Ness and the adjacent Firth of Forth only, the relationship extended to five occasions.

A number of inferences can be drawn with regard to recruitment to the plaice stocks in the areas. In certain years (nine out of the twenty-four in the period reviewed) hydro-biological conditions, whether resulting in good, moderate or poor recruitment, were such as to produce uniform recruitment along the whole coast. The Moray Firth exerts a considerable influence on the rest of the coast, this influence being greatest in the adjacent region Rattray Head–Red Head and decreasing from region to region southwards. Other influences, independent of the Moray Firth and weaker than in that region, exist on the east coast and affect, in particular, recruitment in the two most southerly regions, Red Head–Babbet Ness and the Firth of Forth.

Fulton (1919), from the results of plaice 'marking' experiments, summarised the main spawning localities as follows:— (1) to the south-east of the Bell Rock (east of the Firths of Forth and Tay); (2) at Aberdeen Bank (east of Aberdeen); (3) closer inshore between Aberdeen and Buchan Ness (south of Rattray Head); (4) in the Moray Firth, (a) off Banff, (b) in the Dornoch Firth and (c) off the Caithness coast. Bowman (1914, 1921), from studies of the distribution of plaice eggs, found that the localities in which Fulton's 'marked' spawning plaice were recaptured "were in general agreement with those localities of relatively high frequency of freshly spawned plaice eggs". Bowman also showed that the Moray Firth was the chief plaice spawning area in the northern North Sea and that on the east coast south of the Moray Firth the spawning localities "lie within the triangle the base of which extends from Kinnaird Head (close to Rattray Head) to Berwick, and the apex of which lies in the vicinity of the Long Forties" (about the prime meridian) and that "the locality of greatest egg-content was a lens-shaped area parallel to the coast from the neighbourhood of Montrose northwards to the vicinity of Aberdeen". In addition, he concluded that in the Moray Firth "there is considerable variation in the locality of most intensive spawning from year to year" and that no spawning took place in any of the bays in the Moray Firth or on the east coast or in the Firth of Forth. He related his findings with regard to egg distribution to current movements and showed that, "on the south shore of the Moray Firth eastwards of Lossiemouth (near Spey Bay) the prevailing current carries the eggs in an easterly direction and it is probable that a considerable number of these help later to recruit the inshore grounds on the East of Scotland south of Rattray Head". He stated that conditions on the east coast of Scotland are "complex and observations have not been sufficiently numerous to analyse the conditions fully". From the observations available, however, including returns from drift bottle experiments, he surmised that the lens-shaped area to which he referred "is sandwiched in between the main south-going current and the north-going coastal branch from Fife Ness (in the vicinity of Babbet Ness) and that the westerly branch of the south-going current has a south-westerly set towards the Firth of Forth".

It has not been possible, owing to other commitments, to continue Bowman's investigation of the dis-

ribution of plaice eggs and to relate the results from year to year with the experimental trawling surveys of he area subsequently carried out on the plaice stocks. An attempt was made in 1938 to resume plaice egg lensity distribution surveys in the Moray Firth but this has not been continued. Comparatively few eggs were found (as will be seen from the present review 1938 proved to be an unsuccessful brood year in the Moray Firth) but sufficient evidence was obtained to substantiate Bowman's earlier finding with regard to the drift of eggs southwards past Rattray Head. It will, however, be evident that these present attempts to evaluate the changes which occurred since these earlier years in the various plaice communities along this most important of Scottish plaice areas confirm Fulton's and Bowman's investigations.

Other Scottish Areas

From 1920 plaice age data were collected whenever possible from other Scottish areas. These include Shetland, Orkney, the North Coast of Scotland, and Broad Bay in the Outer Hebrides. In Broad Bay on all occasions and on the North Coast in certain years plaice were the main object of the surveys, but around Shetland and Orkney the data obtained on plaice were largely incidental to other (chiefly haddock) investigations. In spite of many breaks in the continuity of the records, sufficient data are available to provide an approximate picture of the relative year-class abundance in these areas for comparison with the more intensive investigations on the stocks of the east coast. Of particular interest in this connection is the question whether the plaice stocks in these northerly waters are independent of or related to the main stocks, and if related whether collectively or individually.

Brood fluctuation

The percentage age-compositions are given in Appendix Tables 11–14 and Figure 4.

Estimation of abundance has been based on the same relative percentage proportions as in the east coast evaluation. Similarly, the youngest fully represented age-group has been utilised, older groups being used in the absence of, or in confirmation of, values from young fish. The 'standard' ages employed in assessment in the four regions are:— Broad Bay (group II), Shetland (group IV), Orkney and North Coast (group III, *Explorer;* group II, *Kathleen*).

Estimations of the brood strengths are given in chronological order in Table VII, which shows that, of the 19 broods assessed in Broad Bay, six were very good, four good, eight moderate and one poor. At Shetland the 18 broods included one very good, eight good and nine moderate. At Orkney out of 14 broods one was very good, six good and seven moderate. On the north coast the assessment of 14 broods revealed seven good and seven moderate. These results indicate that years of unsuccessful survival were few in each area while successful brood survival was prominent only on Broad Bay.

Area relationships

The extent of inter-area relationships and their connection with the east coast, for example, the Moray Firth, are shown in Table VIII in symbol form. In Table IX, where comparable, coincident years have been integrated by areas and arranged in descending degrees of correlation. In Figure 5 area integrations of the number of coincident years in ten are illustrated.

The four areas exhibit some degree of inter-relationship but this is insufficient to postulate uniformity. Only seven years (1930–36) are comparable for the four areas and in only two of these (1930 and 1932) are the degrees of recruitment in agreement in all four areas. Collectively also they have no connection with the Moray Firth, the same seven years revealing no coincidence of any of these broods. However, agreements which are significantly close exist between certain areas. The most significant are (1) Shetland–Orkney, where in seven years out of ten similar degrees of brood abundance were experienced (see Table IX); (2) Orkney–Moray Firth eight occasions in fourteen years—or six in ten); and (3) Broad Bay–North Coast (five in nine—or six in ten). Following closely on these are (4) Orkney–North Coast and (5) Broad Bay–Shetland, in which the relationships are equally coincident and divergent, while in the remainder of the area combinations divergence exceeds coincidences or is complete.

These widely varying degrees of agreement and disagreement cannot be explained in every case, but some explanations are possible, as might be expected in the light of our knowledge of the spawning movements

Fig. 4. Age-composition of plaice stocks in northern areas, 1920–1952.

TABLE VII

PLAICE BROOD STRENGTHS IN NORTHERN AND NORTH-WESTERN AREAS IN CHRONOLOGICAL ORDER

Brood	Broad Bay	Shetland	Orkney	North Coast
916				prob. M (IV, 30%)
917				M
918				
919		G		
920				
921				G
922	VG (IV, 57%)			
923		prob. G (VI, 19%:>1924)		G
924	VG (II: III)	prob. M		
925	prob. G (IV, 27%)	G		
926	G (III, 40%)	prob. M (V, 19%)		
927	M	prob. M (V, 14%)		
928	VG	VG	M (IV)	
929	prob. M (III, 23%)	G prob. VG(III, IV, V)	M	
930	VG	G (<1929)	G	prob. G (VI, 14%)
931	VG	M	G	prob. M (<1930)
932	M	prob. M	M	prob. M
933	G	G	G	M
934	M	prob. G (V, 26%)	G (III, IV)	M
935	VG (II, III, IV)	M	prob. M	*G
936	M	M	*M	*G
937			*M	*M
938				
939				
940				
941				
942				
943		M (III, IV)		
944		prob. G (V, 30%)		
945		M	*prob. M (III, 21%)	
946	prob. M (V, 15%)		*G	
947	prob. M (<1946)			
948	M			
949	P		*G	*G (I, 54%)
950	G		*VG	*G (II, 39%)
951				

* = "Kathleen" observations

TABLE VIII

PLAICE BROOD STRENGTHS IN NORTHERN AREAS SHOWN SYMBOLICALLY

	1916	'17	'18	'19	'20	'21	'22	'23	'24	'25	'26	'27	'28	'29	'30	'31	'32	'33	'34	'35
Broad Bay							+		+	+	+	1	+	1	+	+	1	+	1	+
Shetland				+				+	1	+	1	1	+	+	+	1	1	+	+	1
Orkney											-		1	1	+	+	1	+	+	1
North Coast						+		+							+	1	1	1	1	+
Moray Firth	(1)	(1)	+	0	1	1	+	+	0	1	1	+	1	1	1	+	0	+	+	+

	1936	'37	'38	'39	'40	'41	'42	'43	'44	'45	'46	'47	'48	'49	'50	'51
Broad Bay	1										1	1	1	0	+	
Shetland	1							1	+	1						
Orkney	1	1								1	+			+	+	
North Coast	+	1												+	+	
Moray Firth	1	+	0	0	(1)	(1)	(1)	(1)	(1)	(1)	+	1	+	1	1	0

Broad Bay	19 years	Positive	10	Intermediate 8	Negative 1
Shetland	18 ,,	,,	9	,, 9	,, 0
Orkney	14 ,,	,,	7	,, 7	,, 0
North Coast	14 ,,	,,	7	,, 7	,, 0
Moray Firth	36 ,,	,,	11	,, 19	,, 6

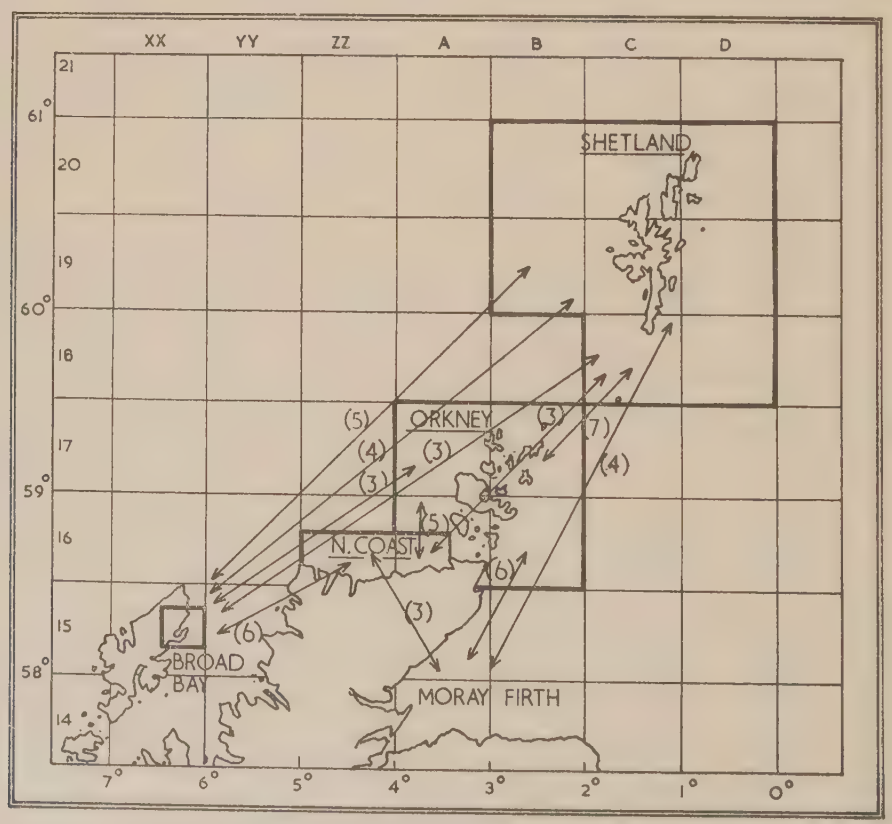

Fig. 5. Plaice brood relationships in northern areas.

and spawning grounds of the plaice and the hydro-dynamic conditions in these areas. In the hydro-dynamic field, Brown (1909), Fulton (1913) and Tait (1930, 1931, 1937) have shown the prevailing current systems over the greater part of the region comprising the four areas concerned. They showed that the prevailing current is easterly to north-easterly from the Atlantic, entering the North Sea in greatest volume round the north of Shetland and to a less degree by the Fair Isle passage between Shetland and Orkney. In these areas subsidiary water movements tend to operate clockwise round these island groups, causing in the Orkney area a residual flow westwards through the Pentland Firth. At the same time, east Orkney grounds in particular, and to some extent the Shetlands, are in some years influenced by a northerly stream from the Moray Firth, tending on those occasions when it is abnormally strong to effect a barrier to the influx through the Fair Isle passage. More recently, Tulloch and Tait (1959), dealing with water movements of the north-western approaches to the British Isles, have demonstrated a coastal flow north-eastwards from west of the Hebrides towards north Orkney and the Fair Isle channel with branches towards the North Coast and west Orkney. Craig (1959) also found evidence of similar water movements, showing in addition the existence of an inflow derived from the west Hebrides stream extending to just south of Broad Bay and an outward flow from the eastern Minch eastwards along the north coast but losing its identity before reaching the Pentland Firth. He concluded from this and from the evidence of Tait (1937) with respect to the westerly set referred to above, that the Pentland Firth will not usually be a point of entry to the North Sea for plankton.

Fulton (1913) showed the main plaice migratory spawning movement to be contranatant, northwards from the Firth of Forth along the east coast to the Moray Firth, with extensions to Orkney and thence westwards along the north coast. He outlined the main spawning grounds on the east coast but not in the areas now being considered. Bowman (1914, 1921), however, showed that spawning took place in Shetland waters, to a less extent east of Orkney and scarcely at all between these island groups in the vicinity of Fair Isle. Although the Fair Isle-Orkney area was not an important spawning ground he argued that from such spawning as occurred there "the eggs are rapidly drifted southwards by the prevailing south-going current". He was also of the opinion that "in all probability a number of plaice eggs is carried into the Moray Firth from the area to the north of Scotland". Bowman (1933) also showed that although the movement of adult plaice in the Shetland area is primarily contranatant, encircling the islands, contranatant leakage, associated with the north-easterly Atlantic flow through the Fair Isle Channel, can occur south-westwards towards the north coast of Scotland. Furthermore, in those years in which the north-going stream from the Moray Firth is strong enough to penetrate to Shetland, pre-spawners may even follow a contranatant path southwards to the Moray Firth spawning ground.

In the extensive region from Orkney westwards to the north coast and the Hebrides, the delineation of spawning localities is incomplete. Although Bowman (1914) found plaice eggs in the North Minch (none in Broad Bay) the numbers were insufficient to establish the Minch as a spawning ground of any importance. Since then trawling surveys have indicated a spawning locality of some importance north of the Hebrides approximately where the current entering the Minch branches from the Hebrides–Fair Isle stream.

Correlating this hydro-biological information with the present assessment of brood relationships in the four areas and their possible connection with the Scottish east coast, some of the relationships emerge in clearer perspective. Thus the close relationships in recruitment to stocks between Shetland and Orkney, between Orkney and the Moray Firth (and the linkage of these three areas) would not appear to be fortuitous but the result of an association of inter-connected hydro-biological conditions. Although not homogeneous in character these stocks are certainly closely related.

Before proceeding to consider the other relationships, attention is drawn to the slender connections between the north coast and the Moray Firth (9) and the north coast and Orkney and Shetland (8) in Table IX. In the former the present recruitment estimations are in agreement with both Bowman's view of the relationship with the Moray Firth and the more definite findings of Tait and Craig that there is little, if any, hydro-dynamic relationship between these adjacent areas. Similarly the weak Shetland–Orkney–north coast connection (three years in ten) would appear to accord with the Orkney Islands water circulatory systems retaining young plaice within the latter area.

Moving westwards now, outside the North Sea, the close relationships between (3) Broad Bay and north coast (six coincident years in ten) and (4) the north coast and Orkney (five in ten) would appear to be associated

TABLE IX

PLAICE BROOD STRENGTHS

Area Combinations	Comparable Years (Coincident Years in bold)		Number	Number Coincident	Number Coincident in 10 years
1) Shetland–Orkney	1928, '29 **'30** '31 **'32** **'33** **'34** **'35** **'36** **'45**	=	10	7	7
2) Orkney–Moray Firth	**1928,** **'29** '30 **'31** '32 **'33** **'34** '35 **'36** '37 **'45** **'46** '49 '50	=	14	8	6
3) Broad Bay–North Coast	**1930,** '31 **'32** '33 **'34** **'35** '36 '49 **50**	=	9	5	6
4) Orkney–North Coast	**1930,** '31 **'32** '33 '34 '35 '36 **'37** **'49** **'50**	=	10	5	5
5) Broad Bay–Shetland	1924, **'25** '26 **'27** **'28** '29 **'30** '31 **'32** **'33** '34 '35 **'36**	=	13	7	5
6) Shetland–Orkney–Moray Firth	1928, '29 '30 '31 '32 **'33** **'34** '35 **'36** **'45**	=	10	4	4
7) Broad Bay–Shetland–Orkney	1928, '29 **'30** '31 **'32** **'33** '34 '35 **'36**	=	9	4	4
8) Shetland–Orkney–North Coast	**1930,** '31 **'32** '33 '34 '35 '36	=	7	2	3
9) North Coast–Moray Firth	**1916,** **'17** '21 **'23** '30 '31 '32 '33 '34 **'35** '36 '37 '49 '50	=	14	4	3
10) Broad Bay–Shetland–Orkney–North Coast	**1930,** '31 **'32** '33 '34 '35 '36	=	7	2	3
11) Broad Bay–North Coast–Orkney	**1930,** '31 '32 '33 '34 **'35** '36 '49 **'50**	=	9	3	3
12) Shetland–Orkney–North Coast–Moray Firth	1930, '31 '32 '33 '34 '35 '36	=	7	0	0
13) Orkney–North Coast–Moray Firth	1930, '31 '32 '33 '34 '35 '36 '37 '49 '50	=	10	0	0
14) All Areas: Broad Bay–Shetland–Orkney–North Coast–Moray Firth	1930, '31 '32 '33 '34 '35 '36	=	7	0	0

with the inter-relationship between the spawning location north of the Hebrides and the Hebrides-Fair Isle–north coast current systems demonstrated by Tulloch and Tait (1959), and Craig (1959). In this connection the higher incidence of very good broods in Broad Bay (the nearest small plaice ground) is significant. To some extent also the comparatively close degree of brood coincidence between (5) Broad Bay and Shetland and the lesser degrees of coincidental brood accessions between (7) Broad Bay, Orkney and Shetland and (10) Broad Bay, North Coast, Orkney and Shetland would appear to be explainable by the same co-ordinative, hydro-biological factors on a more diffused scale.

Although some understanding of the relationship between the biology of the plaice and the hydrodynamics of the Scottish north and east coasts has been achieved much remains to be resolved.

GROWTH

Possibly more than any other species the plaice has been the subject of growth investigations by scientists of the various countries bordering the North Sea. In the course of these investigations, however, all have found it difficult to determine with certainty the average growth of the species. The chief difficulty lies in procuring completely representative material. Ideally it would be necessary to sample all places adequately, evenly and at all depths from the strand region, where the youngest O group stages are located, seawards through the successive overlapping young age-groups to the adult population in the deeper-water, offshore grounds. Such sampling, involving the employment of vessels of suitable draught to cover all depths simultaneously, has been beyond the means of most countries. Further, as Jensen (1938) points out, the selectivity of the gear used and the effect of the removal of the fastest growers of a group results in inaccurate growth values.

In some countries the growth during the first year has been established fairly accurately, but beyond that age-growth investigations have been hampered, and results vitiated, by one or more of the above factors. Thursby-Pelham (1932), dealing with English sampling of the southern North Sea stock, referred to "the impossibility of calculating the *average* rate of growth from either research vessel samples or market samples, at any rate by the methods employed in the past". Later, Buckmann and Kotthaus (1935) stated that in spite of the

xtensive investigations carried out on this fish in the Flemish and German Bights, it was scarcely possible o ascertain the true average growth. More recently, Wimpenny (1953), dealing with southern North Sea laice, gave only "a good indication of average length" of ages one to twenty, the sizes given being based artly on research vessel data (younger fish) and partly on commercial sampling (older fish).

Efforts to fill the gaps by calculation of the lengths of the different age-groups by measurement of the vidth of the growth zones on the otolith have not yielded reliable results (Jensen, 1938), while in Norway Devold, 1942), where growth information on younger fish was lacking, similar back-calculation from the nteroperculum, though yielding more satisfactory results than from otolith measurements, was considered to equire "much closer trial before its efficiency can be definitely decided". Tagging experiments also, for many easons, do not give reliable values (Jensen, 1938).

Early Scottish investigations on the growth of the plaice included tank experiments (Fulton, 1892;

TABLE X

SUMMARY OF EARLY RESEARCHES IN THE GROWTH OF PLAICE

Year	1891 (Masterman, 1895)	1896–97 (Dannevig, 1899)	1900–01 (Fulton, 1902)		1903–09 (Thompson, 1913)
Locality	Firth of Forth and St Andrews Bay	Tynningham Sands (East Lothian)	Aberdeen Bay	Moray Firth (Dornoch Firth)	Average all East Coast Grounds
Depth	?	1–4 fm	6–13 fm	8–12 fm	6–40 fm
Gear used	Beam Trawl	Shrimp Trawl	Otter Trawl and Small Mesh Cover		
		cm	cm	cm	cm
Age 1	14 cm (at 12 months)	7·7	6?	8	9
2	26·7 cm (at 20 months) (above data unsatisfactory)	15·7	12?	17·4	15
3		23·3	21·7	24·6	21
4			31·5	31·7	26
5			39·2	38·2	31
6			45·9	45·0	
7			50·7		

annevig, 1896, 1898), push-net and shrimp-net surveys (Masterman, 1895; Dannevig, 1898; Fulton, 1902), gging experiments (Fulton, 1892, 1919) and estimations based on the Petersen method from size-frequencies otained by experimental trawling (Masterman, 1895; Dannevig, 1898; Fulton, 1902; Thompson, 1913). Vith the exception of Fulton and Dannevig's tank and strand region investigations, which gave reliable enough lues for first year growth, all were subject to limitations of methods and material so that such values as they otained were not claimed to be other than approximations. As a comprehensive record, but also for comparative rposes with subsequent work, these early results have been summarised in Table X. As the later investigations e based entirely on experimental trawling only the results by similar methods from east coast grounds are ven.

Turning to the present investigations from 1920, it has to be admitted that in spite of the advances made more accurate age-determination and of the efforts to improve sampling compared with former years, the rious factors which in the past have prevented the ascertainment of completely accurate growth values have ntinued to present difficulties.

The material used for the purpose of growth estimation is the same as that employed in the previous sec-ons. Most of the data are from the more intensive and continuous surveys of the four regions on the east coast.

The time of sampling of the different populations necessarily varied in the different regions or areas roughout the year and in the different years. In consequence a uniformly common comparative growth

period is not possible from direct observational data. Many of the observations were made from October to March, when growth is stopped, thus providing direct observational values at the end of each year; others were made at different times during the growing period. Again, although the east coast invariably yielded sufficient numbers to provide reliably accurate means for the individual age-groups at all sampling times, the numbers available from the less densely populated and less frequently surveyed regions are only sufficient to provide growth values by summation over the years. The resultant values have been plotted accordingly and linked up to give an average growth curve for each region. In addition, average growth rates of the populations in the separate bays of the Moray Firth are also given, and the effect on growth of extreme variations in brood strength are examined, together with such changes in growth as may have taken place over the years in some of the east coast regions.

Because of the difficulty of accurately determining the ages of old fish, ages eleven and older have been

TABLE XI

PLAICE GROWTH: SCOTTISH EAST COAST, 1920–52

	Average mean lengths and range in means of age-groups at the end of each growth year in the different regions								
	*Moray Firth		‡ Rattray Head –Red Head		Red Head–Babbet Ness		Firth of Forth		Southern North Sea (to nearest 0·5 cm)
Age	Av. cm	Range cm	Av. cm	Range cm	Av. cm	Range cm	Av. cm	Range cm	Av. cm
1	8·1	6—11	8·6	8—10	8·6	7—10·5	9·1	8·5—12	10·0
2	15·1	11·5—20·5	18·8	15—22	14·5	12—18	17·4	14—21	15·5
3	22·2	16—30	26·7	20·5—29	19·9	15—24·5	24·5	20—28	20·0
4	27·1	21—36	30·0	25—34	23·9	192—8·5	28·8	24·5—33·5	24·5
5	30·7	23·5—40·5	33·6	29·5—38	25·5	23—28·5	32·4	26—36	29·0
6	36·0	26·5—43	38·3	33—45	29·3	25·5—33	36·0	29·5—42	—
7	38·0	27·5—44	44·3	38—51·5			39·2	30—45·5	36·0
8	41·2	30—50	48·2	43—55			44·5	36—49	—
9	47·1	36—57	51·8	47—58			49·5	45—55	42·0
10	52·0	47·5—54	51·8	51—52·5			52·8	47—62	—
11–15	57·8	54·5—60·5	55·9	54·5—58·5			56·0	45—62	11 47·5 13 51·5
16–20	67·8	—	66·5	—			61·9	60—64	15 55·0
21–24	70·5	—	—	—			—	—	20 61·5

* Bays only (excluding Inverness Firth) up to age 5; bays plus outer firth from age 6
‡ Aberdeen Bay only up to age 5; Aberdeen Bay plus offshore grounds from age 6

grouped as 11–15 years and 16–20 years. The sexes have been combined but most of the values from fish over ten years of age refer to females only, since few male plaice attain the very old ages.

East Coast Regions

Average growth rates

Disregarding the oldest fish, Table XI and Figure 6 show that the region of best growth on the Scottish east coast extends from Rattray Head to Red Head. This is followed by the Firth of Forth and the Moray Firth, while growth is poorest in the Red Head–Babbet Ness (St Andrews Bay) region. Beyond age ten, in the three regions where such old fish occur, there is some change of the order to Moray Firth, Rattray Head–Red Head, Firth of Forth. This is possibly due to paucity of numbers combined with the five-year groupings; and immigration, for example from the faster growth region Rattray Head–Red Head, may also be responsible in the Moray Firth.

For comparison with these rates of growth the average sizes of southern North Sea plaice, as demonstrated by Wimpenny (1953), are also given in Table XI and Figure 6. These show that after the first year, the growth of plaice in the southern North Sea would appear to be inferior to that of any Scottish east coast region with the exception of the Red Head–Babbet Ness area (St Andrews Bay). It should be noted that St Andrews Bay

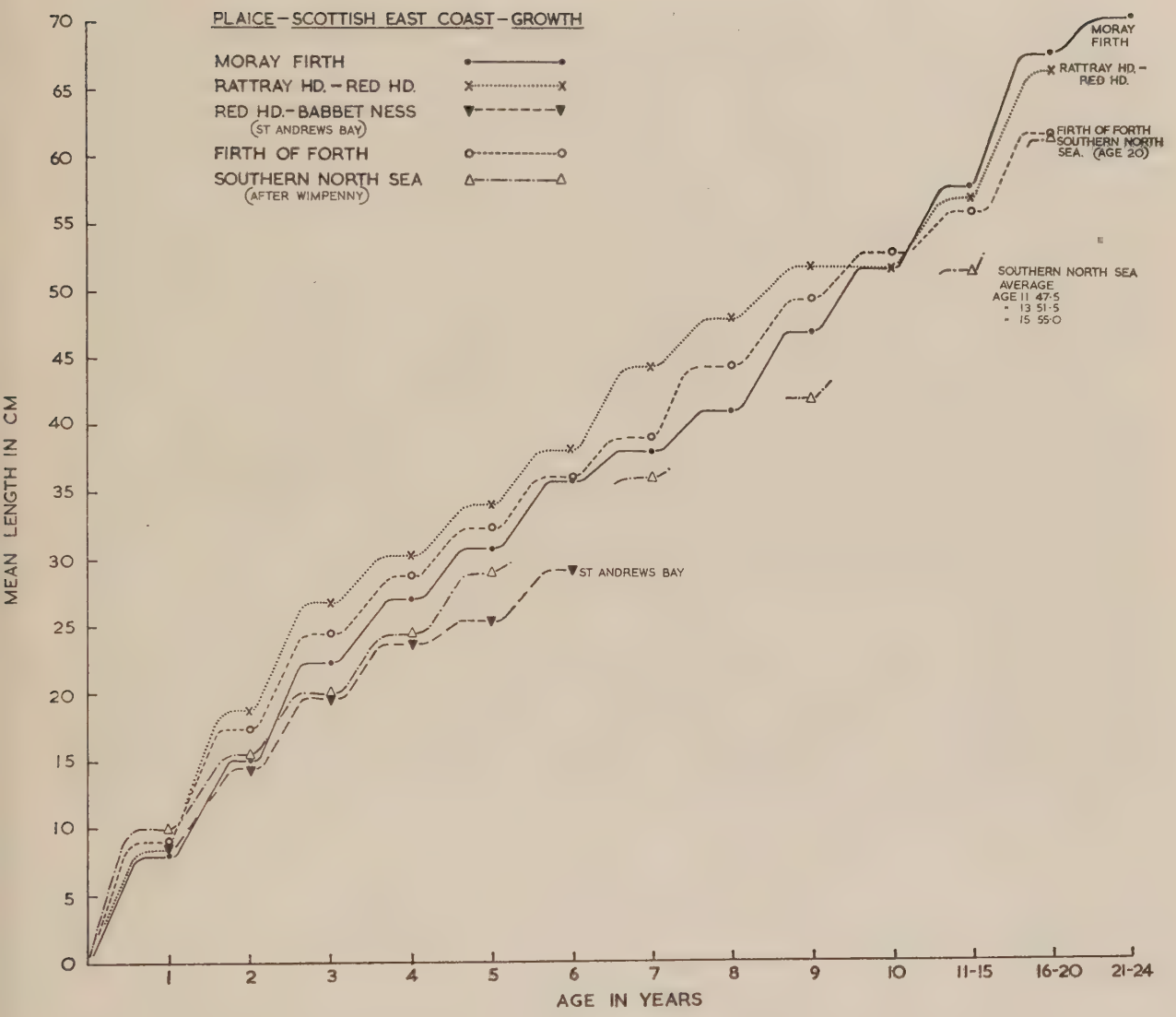

Fig. 6. Growth of plaice in Scottish east coast regions and comparison with southern North Sea.

is the most densely populated plaice ground in Scottish waters. This not only suggests a probable explanation of the slower rate of growth of plaice there compared with that of the other three Scottish east coast regions but also indicates a reason for the similarity to the growth of plaice in the heavily populated southern North Sea.

The Moray Firth bays

The Moray Firth plaice stock is derived principally from several nursery bays within the Firth. These include the Dornoch Firth (the largest and most important of the nurseries), Nairn, Burghead and Spey Bays and, to the eastwards along the south shore, the much smaller bays of Cullen, Sandend, Gardenstown and Aberdour. The 'backwater' inlet of Inverness Firth is also a part of the firth. In their nursery capacity, these bays and subsidiary firths form separate communities varying both locally and annually in the rate of growth of the age-groups composing their baby and adolescent populations. Table XII and Figure 7 illustrate the average sizes of the plaice in these nursery communities up to five years of age. The highest growth values

TABLE XII

PLAICE GROWTH: MORAY FIRTH BAYS

	Dornoch Firth	Nairn Bay	Burghead Bay	Spey Bay	Other Bays	Inverness Firth
			Average Lengths in cm			
Age						
1	9·1	9·1	8·2	7·3	6·7	8·4
2	14·6	15·2	14·8	14·8	16·0	13·3
3	21·6	20·3	21·6	22·2	25·1	17·3
4	26·2	25·3	26·1	27·5	30·6	21·1
5	29·7	28·7	31·0	30·9	35·7	23·8
6	33·5		32·4	33·0		25·7
7	35·5		35·1			
8	37·4					
9	45·3					
10	54·0					
11–15	60·5					
16–20	65·0					
21–24	70·5					

occur in the small, less densely populated bays to the east of Spey Bay. The slowest rate of growth is found in Inverness Firth, where the plaice population is extremely small. These features possibly result from the ecological conditions within this firth, which cannot be regarded as a typical plaice ground. This locality contributes only a very minor quota to the Moray Firth stock and for this reason it has not been considered in the calculation of the present Moray Firth values. The rates in the four main localities are intermediate between these extremes, but although there are differences, they are not sufficiently significant to be termed individually distinctive On average, however, the growth rate tends to be fastest in Spey Bay and slowest in Nairn Bay, with intermediate rates in the Dornoch Firth and Burghead Bay.

Orkney, Shetland, North Coast and Broad Bay

The mean lengths of plaice in the various age-groups from areas to the north of the Moray Firth are given in Table XIII and Figure 8. Growth of plaice is faster at Shetland than on any other of these northern and north-western grounds, and is closely followed by that in Broad Bay. Growth at Orkney is somewhat slower than in these areas throughout all ages, falling appreciably between ages 7 and 10, while apparently recovering somewhat between 11 and 15 years of age. Growth is slowest along the north coast of Scotland where the average sizes are appreciably lower up to three years of age, although evidently improving somewhat from the fourth to the seventh years. No values are available from this region at ages 8, 9 and 10, but from 11 to 20 years of age the few records available suggest that the improvement in growth may possibly be maintained

Plate I

Variations in first year structure of plaice otoliths.

Top left—St Andrews Bay, all group I.
Top right—St Andrews Bay, all group IV.
Bottom left—Aberdeen Bay, groups III, II and IV.
Bottom right—Firth of Forth, all group II.

Plate II

Otoliths of old plaice from the Moray Firth illustrating obscure centres and narrow rings in late years, groups XII–XVI.

Plate III

Top—plaice otoliths from Aberdeen Bay illustrating good growth, "faint" winter rings and radial lines—left, group IV; right, group VIII.

Bottom—otoliths from the Firth of Forth, showing variable, interrupted growth and "faint" and "dark" winter rings—left, groups IV, III and III; centre, doubtful, possibly VI; right, both group VIII.

Part IV

Left—typical St Andrews Bay otoliths showing wide gradation in first year structure, slow growth and the absence of radial lines—all group III.

Right—typical Inverness Firth otoliths showing slow growth, and "dark" winter rings—top row, groups III, III and IV; bottom row, groups V, V and VI.

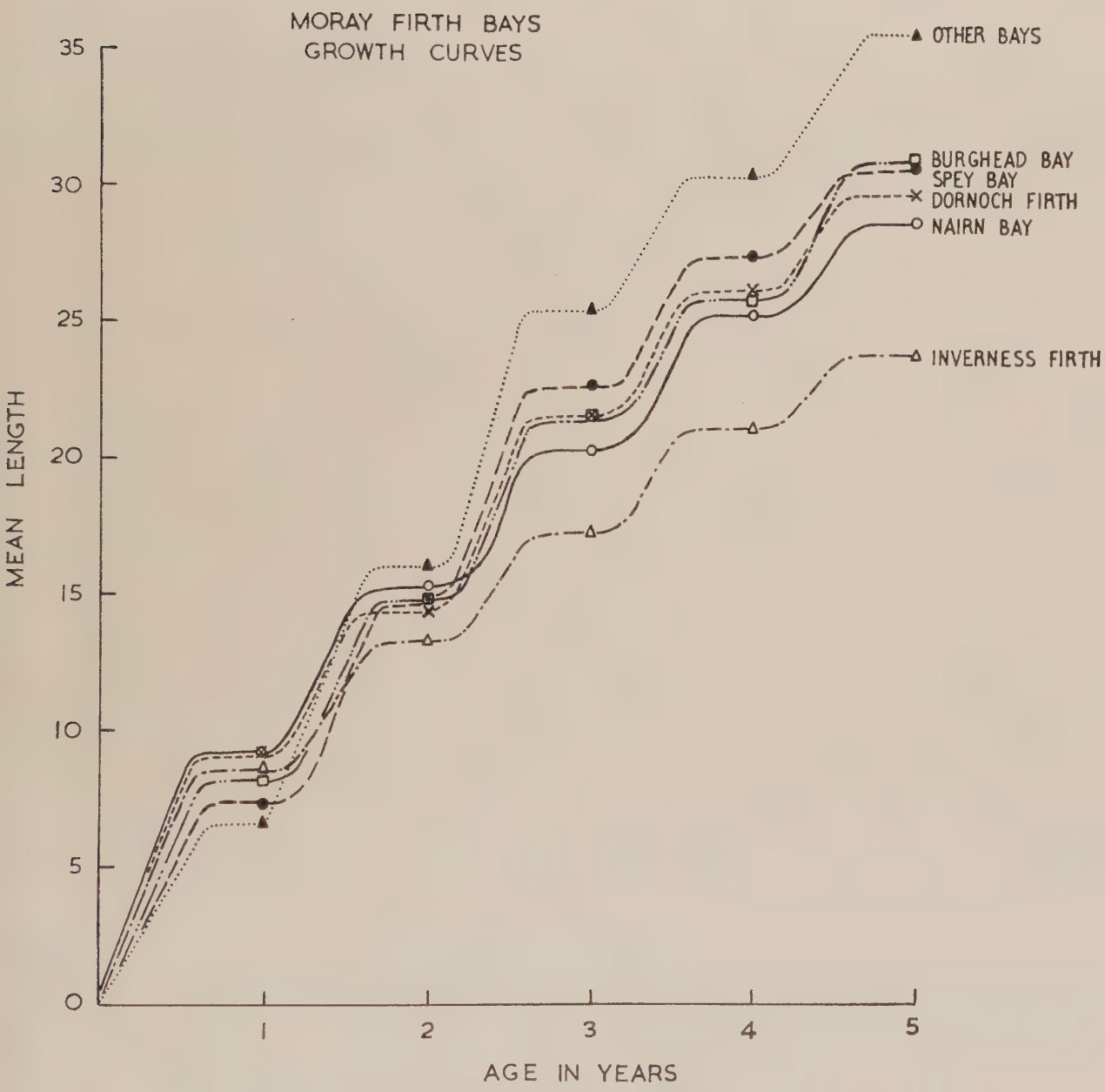

Fig. 7. Growth of plaice in bays and firths of Moray Firth.

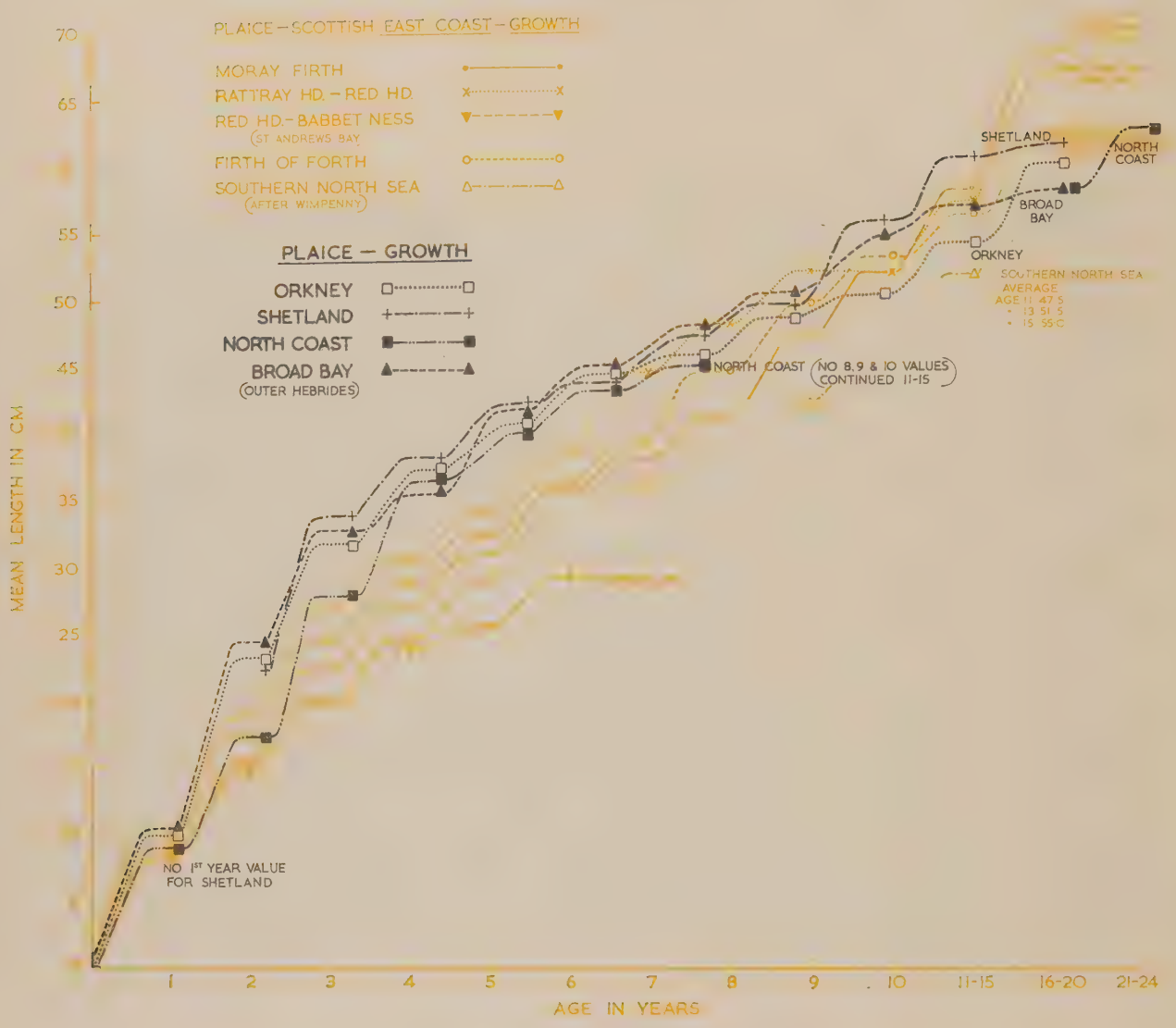

Fig. 8. Growth of plaice in northern areas.

TABLE XIII

PLAICE GROWTH: NORTHERN GROUNDS

MEAN LENGTHS OF AGE-GROUPS AT THE END OF EACH GROWTH YEAR IN CM

Age	Orkney	Shetland	N. Coast	Broad Bay
1	9·0	—	8·0	9·0
2	20·7	20·5	15·5	21·9
3	28·5	30·5	25·0	29·3
4	33·4	34·3	33·5	32·7
5	37·0	37·7	36·6	37·5
6	40·0	39·9	38·7	40·2
7	41·0	43·1	40·8	43·0
8	43·5	44·5	—	45·3
9	45·0	50·0	—	49·0
10	48·6	54·3	—	51·0
11–15	53·8	55·0	52·0	52·0
16–20	—	—	56·0	

beyond age 7. There is a possibility, however, that these growth anomalies may arise as a result of immigration of plaice from other localities.

Comparison of Growth in the Various Regions

A comparison of the growth rates of plaice throughout Scottish waters shows that up to six years of age growth in the northern localities is, in general, more rapid than on the east coast of the Scottish mainland. From six years of age onwards, however, these regional growth distinctions begin to fade, merging or overlapping with increasing age and concluding in some localities in the reversal of their original order. Thus from the sixth to the tenth years growth in the Rattray Head–Red Head region of the east coast improves in comparison to occupy first place among all the regions, after which it tends to yield to that in the Moray Firth; while

TABLE XIV

CHANGES IN THE GROWTH OF PLAICE: SCOTTISH EAST COAST

AVERAGE MEAN LENGTHS OF YEAR-CLASSES FROM AGES 1–5
1915–20, 1921–30, 1931–40 AND 1941–51

	Moray Firth					Aberdeen Bay				
Age Year Classes	1	2	3	4	5	1	2	3	4	5
1915–20	8·0	14·5	22·0	30·5	34·5	—	—	—	—	—
1921–30	10·0	17·0	26·0	30·0	34·0	9·0	18·5	26·0	30·5	32·5
1931–40	8·5	15·0	22·0	27·0	30·0	9·0	19·5	27·0	30·0	34·5
1941–51	8·0	13·0	18·0	23·0	26·5	8·0	16·5	24·0	28·0	32·0
Average all Years	8·5	15·0	22·0	27·5	31·0	8·5	18·5	25·5	29·6	32·5

	St Andrews Bay					Firth of Forth				
Age	1	2	3	4	5	1	2	3	4	5
1915–20	—	—	24·5	26·5	—	—	20·0	27·0	32·0	35·0
1921–30	8·5	14·0	19·5	23·0	26·0	9·0	19·0	24·5	29·0	32·5
1931–40	9·0	16·0	21·5	26·0	—	9·0	18·0	26·0	30·5	35·0
1941–51	8·5	13·5	18·5	22·5	24·5	10·0	16·0	22·0	26·0	29·0
Average all Years	8·5	14·5	20·0	24·0	25·5	9·0	18·0	24·5	29·0	32·5

after the seventh year growth in the Firth of Forth exceeds the previously superior growth of the Orkney, Shetland, and Broad Bay grounds. The growth of plaice in all Scottish regions except St Andrews Bay is faster than in the southern North Sea.

Changes in the Rate of Growth

The variable rates of growth within the same region and the probable connection of the variations with density, whether of the total population or of individual year-brood abundance, have always been important factors in the fishery biology of plaice and indeed of other species of commercial importance. In the investigations under review it was not possible to assess density except relatively, and only then so far as individual broods were concerned on the more intensively surveyed east coast grounds.

Table XIV and Figure 9 give the average mean lengths at the end of each year's growth of the first five age-groups over the four periods 1915–20, 1921–30, 1931–40 and 1941–51 in the four east coast regions. Quite significant changes are shown to have occurred during the years under review. Most outstanding is the decrease in growth that occurred in all regions at all these ages during the period 1941–51 spanning the second war and the years which followed it. The reason for this decline is not clear but it may be a result of the fishing out of the faster growing fish following the increased intensity of seining after the second war.

Prior to these years changes in growth were variable, certain regions showing increases and others decreases compared with the 1915–20 period. Thus in the Moray Firth an appreciable increase occurred in 1921–30 up to age four, while in 1931–40 a slight increase up to age three was offset by significant growth depression at

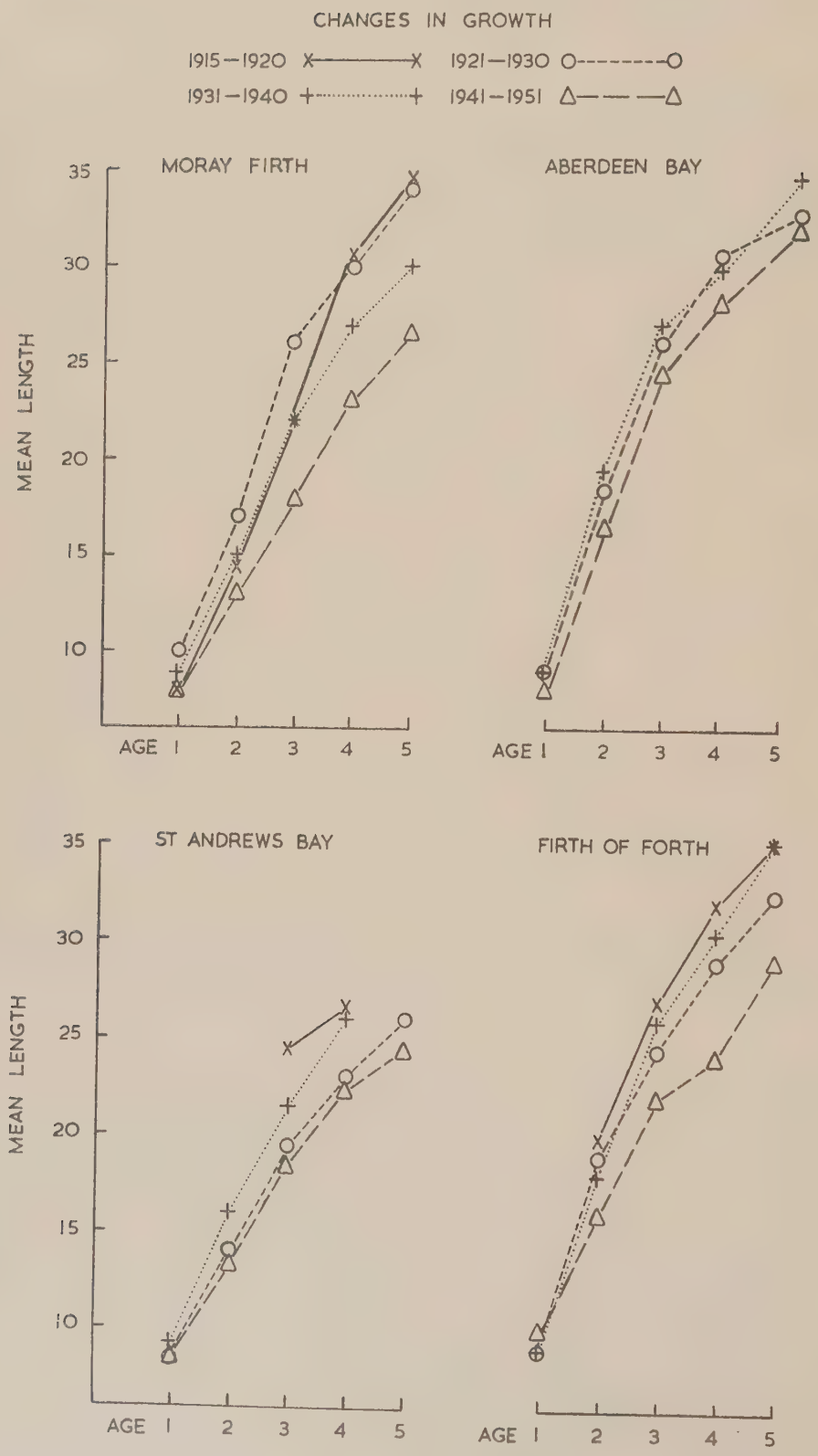

Fig. 9. Changes in the growth of plaice on the Scottish east coast,

ges four and five. In Aberdeen Bay no values are available for the earliest years 1915–20, but some slight nprovement in growth is evident in 1931–40 compared with the previous decade, 1921–30. In St Andrews ay and the Firth of Forth growth in 1931–40 also increased appreciably over that of 1921–30 but in the Firth f Forth the values for these two decades are lower compared with the earlier years 1915–20.

The Relationship Between Growth and Brood Strength

The growths in the years of good–very good and poor–very poor abundance in the four east coast regions re compared in Table XV. The average of the mean values of these two extreme abundance groups and the alues of the estimated prolific year-classes are illustrated in Figure 10. These show that it cannot be definitely oncluded that brood strength affects growth except in very extreme cases. If the averages of the means of he two groups are compared, it will be seen that only in the Moray Firth did the growth of poor–very poor ear-classes exceed that of good–very good year-classes. In Aberdeen Bay, on the other hand, poor–very poor alues are lower, while in St Andrews Bay and the Firth of Forth only in the first and second years does rowth of a weak brood exceed on average that of an abundant one. On the other hand, there is conclusive vidence that in the few instances when exceptionally productive years occur, for example in St Andrews Bay 1 1927 and 1946, and in the Firth of Forth, to some extent, in 1946, growth of such abundant broods may be onsiderably depressed.

SUMMARY

The age-composition, like the size-composition, of the plaice stocks on Scottish east coast grounds changed onsiderably from 1920 to 1952. Owing to the increase in the landings of plaice which followed the expansion f the Scottish seine-net fishery between the two wars, and especially since the end of the second war, the verage age of this species in Scottish waters has declined in a marked manner in all localities.

Fluctuations have been observed in the brood strengths from year to year, but the danger of an overall ailure in any year is largely diminished by the regional character of the fluctuations, which generally ensures uccessful or adequate recruitment to the stocks in one or more localities.

Average sizes, calculated for each age-group in each Scottish area, have been used to illustrate the regional rowth rates of the plaice. The best growth on the Scottish east coast occurs from Rattray Head to Red Head, hile growth is poorest in St Andrews Bay. The growth rates in the various plaice nurseries of the Moray irth show better growth in the smaller bays along the eastern half of the southern shore than in the major urseries at the western end of the firth. The effect of brood strength on growth within the various nurseries discussed.

Brood fluctuations in a number of minor plaice grounds have also been considered along with the possible ffect of water movements on the distribution of young plaice on these and on the main east coast grounds.

The validity of the otolith method of age determination and its application to Scottish plaice is dealt with the Appendix.

TABLE XV

GROWTH-BROOD STRENGTH RELATIONSHIP IN PLAICE

MEAN SIZES AT END OF GROWTH PERIOD OF INDIVIDUAL GOOD—VERY GOOD AND POOR—VERY POOR YEAR-CLASSES UP TO AGE FIVE

Good—Very Good Years

Moray Firth

	1911	1913	**1918**	**1922**	**1923**	1927	**1931**	**1933**	**1934**	1935	1937	1946	1948	Av.
Age 1	—	—	—	—	—	10·0	8·5	8·0	8·5	7·5	8·5	—	7·5	8·5
2	—	—	15·5	—	—	—	14·5	15·5	15·0	14·5	13·5	13·5	13·0	14·5
3	—	—	23·0	—	—	28·5	23·0	22·0	22·5	22·0	—	18·5	19·0	22·5
4	—	—	29·5	—	31·5	29·5	26·5	26·5	27·5	24·0	—	23·0	23·0	27·0
5	—	—	—	39·0	—	35·0	—	28·5	31·0	—	—	28·0	28·0	31·5

Rattray Head—Red Head

	1918	1920	1921	* **1923**	1925	**1927**	1928	**1931**	**1933**	**1934**	**1935**	**1937**	**1946**	**1948**	**1950**	Av.
Age 1	—	—	—	9·0	—	—	—	8·0	9·0	10·0	8·5	9·5	—	8·0	8·5	9·0
2	—	21·0	21·0	18·5	—	20·5	20·5	18·5	21·5	19·0	18·5	21·0	16·5	16·0	16·5	19·0
3	33·0	29·5	30·0	24·5	23·5	27·0	26·5	26·5	29·0	26·0	25·0	27·0	25·5	24·0	24·5	27·0
4	34·0	32·5	33·5	27·5	31·5	31·5	33·5	30·0	—	31·0	29·5	—	27·0	30·0	—	31·0
5	38·0	—	37·0	33·0	**33·0**	—	—	—	—	—	34·5	—	29·5	35·0	—	34·5

Red Head—Babbet Ness

	1921	**1922**	**1923**	**1925**	* **1927**	**1931**	**1933**	**1934**	**1935**	**1938**	**1945**	**1946**	Av.
Age 1	—	7·0	9·0	9·0	7·5	8·5	9·0	9·0	8·5	10·0	—	—	8·5
2	18·0	13·5	16·0	15·0	10·5	14·5	15·5	14·0	14·5	—	—	12·0	14·5
3	21·0	20·0	21·0	20·5	15·0	21·0	21·5	21·5	20·5	—	19·0	17·0	20·0
4	26·0	23·5	27·0	21·5	19·0	27·0	25·0	25·0	25·0	—	23·0	21·0	24·0
5	—	27·5	28·5	23·0	24·0	—	—	—	—	—	24·5	23·0	25·0

Firth of Forth

	1919	1921	1922	1925	1926	**1927**	**1931**	1932	1933	1934	**1935**	1938	* **1946**	1949	1950	Av.
Age 1	—	—	—	—	—	—	9·0	9·5	8·0	8·5	—	9·0	—	10·0	10·0	9·0
2	20·0	20·5	—	17·5	18·0	17·0	17·5	17·0	17·5	—	19·5	—	14·0	16·5	15·0	17·5
3	—	26·0	24·0	22·5	24·0	22·5	24·5	26·5	26·5	26·0	24·5	—	23·5	22·0	20·5	24·0
4	31·0	31·5	31·5	28·0	27·0	27·0	29·5	32·0	31·5	28·0	31·0	—	26·5	25·5	—	29·0
5	34·0	35·5	32·5	31·0	30·5	32·5	37·0	33·5	35·0	34·0	—	—	—	—	—	33·5

Very good broods in bold type
* Prolific broods

Poor—Very Poor Years

Moray Firth

	1919	**1924**	**1932**	1938	1939	1951	Av.
Age 1	—	—	10·0	9·0	—	8·0	9·0
2	14·0	—	17·5	—	—	14·0	15·0
3	19·5	24·5	25·0	—	—	—	23·0
4	—	—	31·0	—	—	—	31·0
5	—	—	—	—	—	—	—

Rattray Head—Red Head

	1919	1922	**1924**	**1932**	1936	**1949**	
Age 1	—	—	—	10·0	—	8·0	9·0
2	22·0	20·5	15·0	20·5	17·5	16·5	18·5
3	30·5	27·0	20·5	28·0	27·0	24·0	26·0
4	33·5	33·5	29·0	—	30·0	29·5	31·0
5	35·5	—	33·0	—	—	—	34·5

Red Head—Babbet Ness

	1924	**1928**	1937	1947	1948	
Age 1	10·5	8·5	9·5	8·0	9·0	9·0
2	16·5	12·5	19·5	14·5	15·5	15·5
3	22·5	17·0	—	18·0	19·5	19·0
4	26·0	—	—	21·0	23·0	23·5
5	—	—	—	24·0	—	24·0

Firth of Forth

	1924	1928	1947	1951	
Age 1	—	—	9·0	10·5	10·0
2	—	21·0	17·0	16·0	18·0
3	24·0	24·0	20·0	—	22·5
4	27·5	30·0	24·5	—	27·5
5	32·0	33·0	28·0	—	31·0

Very poor broods in bold type

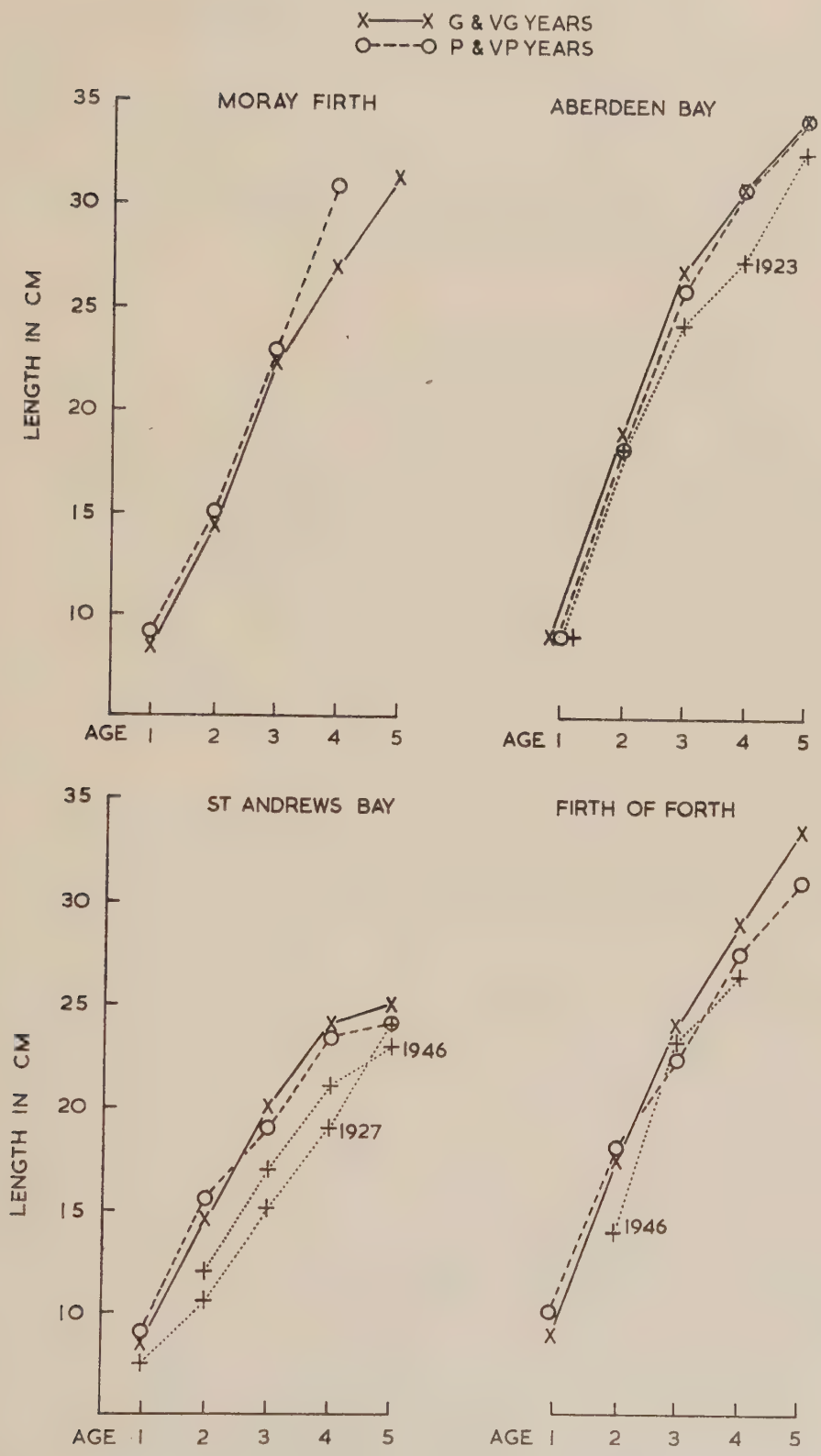

Fig. 10. Comparison of the growth of plaice in years of high and low population density.

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APPENDIX

THE VALIDITY OF THE OTOLITH METHOD OF AGE-ESTIMATION IN SCOTTISH PLAICE

Although Reibisch's (1899) discovery of the correlation of ring formation on the otoliths of the plaice with age has been accepted and successfully applied, the method, as several investigators have since shown, is not infallible and presents many difficulties. Graham (1929), in his review of the literature on the use of fish skeletal structures generally for the purpose of age-determination, found that there were "differences of opinion as to what constitutes an annual ring" and this disagreement "renders the evidence for the method less convincing than it would be had all workers agreed that they could at least see and similarly interpret the same phenomena." Later, Buchanan-Wollaston (1933) expressed the view that "the method of age-determination of plaice by otolith reading cannot be regarded as infallible by any means" and that "it must in all districts be checked by back calculation . . ." He apparently intended to publish fuller results on anomalies in otolith ring formation but did not do so. More recently Margetts and Williams (1949) discussed the question of anomalies and difficulties encountered in plaice otolith reading and the extent to which divergence in readings can affect an age census. By descriptions and photographs they showed how anomalies in ring formation may be more accurately interpreted but suggest that these might also be investigated by measurement and by a study of the physiology of otolith formation.

Scottish scientists were much later than those of other countries bordering the North Sea in accepting the validity of the otolith method of age-determination. Although the pioneer work by Reibisch was quickly confirmed by English German, Dutch and Danish investigators (Wallace, 1905, 1907; Heinke, 1905; Redeke, 1905; Johansen, 1906), early Scottish investigators were not convinced of its reliability. Cunningham (1905) disagreed with Reibisch as to the seasons in which the opaque and clear zones of plaice otoliths are formed, and later Maier (1908) supported Cunningham. Thompson (1913) examined an insufficient number of plaice otoliths to reach definite conclusions, while Williamson (1918) criticised Reibisch's whole method of estimating the age of plaice. Graham says of Williamson:— "his criticism of the argument of Reibisch's paper is in fact pertinent and searching and had it been published before Wallace's paper (1907) it must have left the validity of the method open to considerable doubt."

Up to 1918, therefore, the validity of the method was not accepted by Scottish workers. Dr A. Bowman, Superintendent of the Marine Laboratory at Aberdeen until 1935 (unpublished), was convinced, however, that the method was applicable to Scottish plaice and that the many apparent difficulties were not peculiar to Scottish fish but were probably accentuations of similar difficulties found in otoliths of southern North Sea plaice caused by the over-crowded conditions of the Scottish bays and firths at that time, and that the uncertainty was, in part, owing to the scarcity of sufficient O group and I group material for the study of the earliest zonal markings. Investigations were, therefore, continued, first from 1919 to 1922 in fulfilment of obligations to the International North Sea Plaice Investigations Committee and, when these ceased without wholly satisfactory results being obtained, in continuation of purely Scottish problems raised after 1921 by the introduction and expansion of seine-net fishing in inshore areas. Under Bowman's guidance old and new material from all Scottish grounds was examined and re-examined and large numbers of nuclear, l_1, l_2 etc. calculations made and checked against directly observed length measruements. By these means and by the more intensive and continuous sampling begun in 1931 of the youngest age-groups in the shallower depth zones the complexity of individual, local and annual variations in otolith characteristics and their attendant anomalies, which no doubt were the cause of Cunningham's and Williamson's objections to the method and of Thompson's inconclusive results, came to be recognised and resolved to within an acceptable margin of error.

In this connection most published works on age census of plaice indicate in only a general way the incidence of 'age doubtful' or 'unreadable' otoliths and their causes. Where specific examples are given they vary widely. Blegvad (1927) found less than 2% of otoliths difficult to read in the Belt Sea and Southern Kattegat, the ages concerned ranging up to group V, but consisting mostly of groups I–III. Buchanan-Wollaston (1933) found not more than 5% of doubtful age in his investigations of similar young stock at Poole and Beer in the western English Channel. In an experimental transplantation of plaice from the Dutch coast to Poole, however, he reckoned that anomalous rings were the cause of 10% of wrong age-determinations. Wimpenny (1947), working on plaice from Rye Bay in the eastern English Channel, was

obliged to reject 30% (ages I–IX+) owing to thick, split or incomplete white rings which could not be interpreted. Margetts and Williams (1949), in their sampling of commercial landings at Lowestoft in 1948, rejected 17% of 13,000 otoliths examined, the incidence of plaice of doubtful age in any one sample lying between 8% and 30% though nsually between 12% and 25%. The difficulties and anomalies giving rise to these proportions included some similar to those of Buchanan-Wollaston and Wimpenny and covered a wide range:—
(1) the difficulty of counting rings in old fish (in this connection they refer to the change in appearance of rings in fish with increasing age); (2) the difficulty of accurate determination of the first year; (3) 'double' rings; (4) 'split' rings; (5) 'false' rings; (6) otoliths in which ring formation is absent or vague; and (7) otoliths of different sizes from the same fish showing different numbers of rings.

These have all been encountered in the Scottish age-determinations (although nomenclature or classification differ in some respects) and have led to the same difficulties in interpretation and in the incidence of 'age-doubtful' or 'unreadable' types. In the material collected in the early years from 1919 to 1925, and even in some regions up to 1930, these were initially very high, 40% to 50% being common and under 20% rare. These proportions have been reduced, however, both in the early samples and in subsequent material, to between 3% and 20%, narrowed in general to 5%–12%. This has been effected, as already stated, partly by measurement and, after 1931, by the taking of larger numbers of otoliths, especially from those regions from which the otoliths have come to be recognised as consistently difficult.

Of the various difficulties the determination of the first year, probably more than any other, has caused greatest doubt, especially in the early years when the O and I groups were insufficiently represented in the samples. Margetts and Williams experienced this 'first-year' difficulty and also the change in definition of early rings in old fish. Both these features have been prominent in Scottish otoliths. Local and annual differences and gradations in the distinction of the nuclear ring formation have proved to be extremely variable, and the tendency for the central portions of old, thick otoliths to become obscured has raised doubts as to the correct age-determination in old fish, especially in those from offshore grounds where the stocks may comprise plaice from different sources. Crowding of the narrowing rings in the otoliths of old fish also made accurate age-determination difficult. Early measurements helped to some extent to overcome these particular difficulties but it was not until larger samples became available that greater accuracy was possible. Otoliths featuring these difficulties are shown in Plates I and II.

Improved sampling also aided the clarification of other difficulties and anomalies arising out of variations in checks or subsidiary ring formation.

The causes of the differences in normal ring formation or of the many anomalies that occur have not been investigated. Through observations over the years, however, a certain relationship has been found between the character of zonation and the density of the plaice population and, more significantly, the physical or environmental conditions under which some plaice communities exist. Density of population and its associated growth seem to determine the degree of definition of the nucleus and to influence the time of appearance, the width and the nature of the stratification of both the spring-early summer opaque zone and the late autumn–winter translucent zone, all of which affect the ease and speed of age determination. In this connection Buchanan-Wollaston (1933) found otoliths most easily interpreted and the lowest incidence of doubtful readings where growth was greatest. The best plaice growth on the Scottish east coast occurs in Aberdeen Bay, where otoliths approach nearest to the ideal by presenting the least difficulty in determining the first year and by exhibiting broad opaque zones, the steady slowing-down and formation of the clear zone and the appearance in the complete structure of radial lines (Plate III), a feature of fast growth described by Margetts and Williams. Exceptions cur, however, in other localities, notably the Firth of Forth, where good growth may be temporarily interrupted by the sudden onset of late summer–autumn conditions and give rise to suspicions of a false ring (Plate III).

On the other hand the effect of population density on growth is reflected in various features of the otolith; these include a wider gradation in the definition of the nuclear structure, a delay in the appearance of the opaque zone at the beginning of the growth period, narrowing of both the opaque and the clear zones and the absence of radial lines (Plate IV, St Andrews Bay). The resemblance of anomalous-ring formation to normal seasonal zoning, however, can be very close, and without a fuller knowledge of its cause cannot be explained solely by the density-growth factor. In this connection Margetts and Williams (1949) regard the abnormal climatic conditions which occurred in the southern North Sea in 1947 as a possible cause of the high incidence of anomalous rings found in samples in 1948 and 1949, but are not satisfied that this was the only cause. Scottish otoliths, particularly in the Moray Firth, gave similar difficulty in these years, but as high density of several successive year-broods occurred simultaneously, the apportioning of the responsible factor is difficult to assess.

The causes of the different types of normal zonation, resulting from physical or environmental conditions, appear to be more easily explained. Two main types have been recognised to which the terms 'faint' and 'dark' have been applied with reference to the clear or translucent zone. In the 'faint' type zonation is of a delicately traced nature, while in the 'dark' type the clear zone is exceptionally dark, and the opaque zone more intensely white in contrast.

The two types are subject to individual and local variation in intensity, while a small proportion may show gradations which preclude definite assignment to either category. Nevertheless, the distinction is quite apparent and in instances where the two types occur together is of a pronounced nature.

The significant feature about the two types is that their occurrence is closely related to the nature of the bottom. The 'faint' type is associated with a habitat such as Aberdeen Bay (Plate III), the Moray Firth bays (except Inverness Firth) and St Andrews Bay, in which the sea bottom consists entirely of sand, although the 'dark' type also occurs occasionally in the latter two areas. The 'dark' type on the other hand occurs where the bottom is of mud—in Inverness Firth, in

the Firth of Forth and southwards along the East Lothian and Berwickshire coasts. In Inverness Firth, where pure estuarine mud conditions prevail, almost 100% of the plaice population have 'dark' otoliths (Plate IV). In the Firth of Forth where mud and sand occur in close proximity a mixture of the two types is found, in the ratio of about four 'light' to one 'dark' with a small proportion showing both 'dark' and 'light' characteristics (Plate III). South of the Firth of Forth, on the East Lothian and Berwickshire coasts, the 'dark' type tended to predominate in the few years in which these grounds were surveyed.

It is noteworthy that the 'dark' type is invariably linked with slow growth and this suggests that the correlation of the intensity of zonation with the nature of the bottom is further related to the nature of the food. According to Ritchie (1938) the food of plaice in Inverness Firth and in the Firth of Forth (the food on the East Lothian and Berwickshire coasts was not investigated) is characterised by features which are not evident in other east coast localities where the 'faint' otolith type predominates. Although this apparent relationship has not been investigated in detail, some correlation clearly exists.

An attempt was made in 1938 to investigate the extent of possible plaice infiltration into the Firth of Forth from St Andrews Bay, where 'faint' otoliths predominate, and from the East Lothian and Berwickshire coasts, where the 'dark' type prevails. This attempt to establish the ratio of indigenous to immigrant fish was interrupted by the second war and unfortunately has not been resumed.

A sample of plaice otoliths from off north-eastern England showed that 92% were of the 'dark' type. Apart from this sample no otoliths from the southern North Sea have been examined at Aberdeen except through photographs (Wallace, 1907; Buchanan-Wollaston, 1933; Margetts and Williams, 1949.) The impression gained, however, is that they also resemble the Scottish, muddy-bottom, 'dark' variety.

Various techniques have been tried in the reading of plaice otoliths. In these Scottish investigations the most satisfactory restults have been obtained by viewing the otoliths in water on a black background with reflected light under a low-power lens. In some samples accuracy can be obtained simply by the naked eye but, in general, a hand lens of x3 magnification was used. A higher power magnifies the minute structure so much that it tends to confuse rather than clarify. In otoliths from old fish, however, where the rings are close together, a higher power is sometimes necessary to distinguish them, transmitted light through the otolith also being used as a check in old fish and as an aid in suspected anomalies.

It has, then, been found that the age-determination of plaice, though valid, can often be fraught with difficulty. Little experience is necessary in reading normal otoliths but the correct interpretation of anomalies requires training and experience. One acquires with practice a certain aptitude, intuition or otolith-reading sense based on accumulated mental pictures of thousands of observations but even this faculty is far from being infallible. Large numbers of otoliths, measurements and accumulated experience have helped in producing acceptable results but there is no doubt, as Margetts and Williams suggest, that a knowledge of the physiology of otolith formation is essential if still better results are to be obtained.

APPENDIX TABLE 1

AGE-COMPOSITION OF PLAICE IN MORAY FIRTH

Series 1. "Goldseeker"—"Explorer", 1920–30, 1936
Inner Firth (Dornoch Firth, Nairn Bay, Burghead Bay) <20 fm

Year of sampling	Age-group	I	II	III	IV	V	VI	VII	VIII	IX	X+	Total
	No.	31	800	159	135	71	29	44	20	13	36	1,338
1920	%	2·3	59·8	11·9	10·1	5·3	2·2	3·3	1·5	1·0	2·7	
	Year-class	1919	1918	1917	1916	1915	1914	1913	1912	1911	1910—	
	No.	99	214	484	251	78	45	14	40	13	56	1,294
1921	%	7·7	16·5	37·4	19·4	6·0	3·5	1·1	3·1	1·0	4·3	
	Year-class	1920	1919	1918	1917	1916	1915	1914	1913	1912	1911—	
	No.	37	233	93	196	25	7	4	—	8	9	612
1922	%	6·1	38·1	15·2	32·0	4·1	1·1	0·7	—	1·3	1·5	
	Year-class	1921	1920	1919	1918	1917	1916	1915	1914	1913	1912—	
	No.	100	91	65	40	44	4	—	—	—	2	346
1923	%	28·9	26·3	18·8	11·6	12·7	1·2	—	—	—	0·6	
	Year-class	1922	1921	1920	1919	1918	1917	1916	1915	1914	1913—	
1924–25		no observations										
	No.	—	4	92	124	22	12	—	—	—	2	256
1926	%	—	1·6	35·9	48·5	8·6	4·7	—	—	—	0·8	
	Year-class	1925	1924	1923	1922	1921	1920	1919	1918	1917	1916—	
	No.	23	101	32	129	11	3	2	1	1	2	305
1927	%	7·5	33·1	10·5	42·3	3·6	1·0	0·7	0·3	0·3	0·7	
	Year-class	1926	1925	1924	1923	1922	1921	1920	1919	1918	1917—	
	No.	7	3	7	—	11	5					33
1928	%	21·2	9·1	21·2	—	33·3	15·2					
	Year-class	1927	1926	1925	1924	1923	1922					
	No.	1	25	21	16	2	3	1				69
1929	%	1·5	36·2	30·4	23·2	2·9	4·4	1·5				
	Year-class	1928	1927	1926	1925	1924	1923	1922				
	No.	5	220	307	43	22	2	1				600
1930	%	0·8	36·7	51·2	7·2	3·7	0·3	0·2				
	Year-class	1929	1928	1927	1926	1925	1924	1923				
	No.	2,496	9,404	6,618	84	12						18,616
1936	%	13·4	50·5	35·6	0·5	0·1						
	Year-class	1935	1934	1933	1932	1931						

APPENDIX TABLE 2

AGE COMPOSITION OF PLAICE IN MORAY FIRTH BAYS
Series 2. "Enid"—"Kathleen", 1931–52, 2–10 fm

Year of sampling	Age-group	I	II	III	IV	V	VI+	Total
	No. per hr	11	9	7	4	1		32
1931	%	34·4	28·1	21·9	12·5	3·1		
	Year-class	1930	1929	1928	1927	1926		
	No. per hr	146	27	8	1	1		183
1932	%	79·8	14·8	4·4	0·5	0·5		
	Year-class	1931	1930	1929	1928	1927		
	No. per hr	29	96	13	3	1		142
1933	%	20·4	67·6	9·2	2·1	0·7		
	Year-class	1932	1931	1930	1929	1928		
	No. per hr	169	21	36	2			228
1934	%	74·1	9·2	15·8	0·9			
	Year-class	1933	1932	1931	1930			
	No. per hr	207	97	4	3			311
1935	%	66·6	31·2	1·3	0·9			
	Year-class	1934	1933	1932	1931			
1936		see Appendix Table 1						
	No. per hr	66	77	35	8			186
1937	%	35·5	41·4	18·8	4·3			
	Year-class	1936	1935	1934	1933			
	No. per hr	66	73	54	9	1		203
1938	%	32·5	35·9	26·7	4·4	0·5		
	Year-class	1937	1936	1935	1934	1933		
	No. per hr	59	203	113	42	1		418
1939	%	14·1	48·6	27·0	10·0	0·3		
	Year-class	1938	1937	1936	1935	1934		
1940–45		no observations						
1946		see Appendix Table 3						
	No. per hr	245	118	108	9	1		481
1947	%	50·9	24·5	22·5	1·9	0·2		
	Year-class	1946	1945	1944	1943	1942		
	No. per hr	185	165	149	138	8	3	648
1948	%	28·5	25·5	22·9	21·3	1·3	0·5	
	Year-class	1947	1946	1945	1944	1943	1942	
	No. per hr	201	152	40	36	8	1	438
1949	%	45·9	34·7	9·2	8·2	1·8	0·2	
	Year-class	1948	1947	1946	1945	1944	1943	
	No. per hr	39	71	61	10	4	1	186
1950	%	20·9	38·2	32·8	5·4	2·2	0·5	
	Year-class	1949	1948	1947	1946	1945	1944	
	No. per hr	118	71	69	20	2	1	281
1951	%	42·0	25·3	24·6	7·1	0·7	0·4	
	Year-class	1950	1949	1948	1947	1946	1945	
	No. per hr	15	58	103	43	29	1	249
1952	%	6·0	23·3	41·4	17·3	11·6	0·4	
	Year-class	1951	1950	1949	1948	1947	1946	

APPENDIX TABLE 3

AGE-COMPOSITION OF PLAICE IN MORAY FIRTH
Series 1. "Goldseeker"—"Explorer", 1920–22, 1946, 1949–52
Outer Firth, 20–50 fm

Year of sampling	Age-group	I	II	III	IV	V	VI	VII	VIII	IX	X+	Total
	No.	—	1	1	3	7	6	12	9	10	10	59
1920	%	—	1·7	1·7	5·1	11·9	10·2	20·3	15·2	17·0	17·0	
	Year-class	1919	1918	1917	1916	1915	1914	1913	1912	1911	1910—	
	No.	—	—	4	8	19	19	15	14	5	16	100
1921	%	—	—	4·0	8·0	19·0	19·0	15·0	14·0	5·0	16·0	
	Year-class	1920	1919	1918	1917	1916	1915	1914	1913	1912	1911—	
	No.	—	1	2	12	9	8	3	2	4	7	48
1922	%	—	2·1	4·2	25·0	18·8	16·7	6·3	4·2	8·3	14·6	
	Year-class	1921	1920	1919	1918	1917	1916	1915	1914	1913	1912—	
	No.	—	2	4	10	6	4	—	2			28
1946	%	—	7·1	14·3	35·7	21·4	14·3	—	7·1			
	Year-class	1945	1944	1943	1942	1941	1940	1939	1938			
	No.			16	28	24	6	6	6	—	4	90
1949	%	—	—	17·8	31·1	26·7	6·7	6·7	6·7	—	4·4	
	Year-class	1948	1947	1946	1945	1944	1943	1942	1941	1940	1939—	
	No.		2	38	34	4						78
1950	%		2·6	48·7	43·6	5·1						
	Year-class	1949	1948	1947	1946	1945						
	No.		50	71	116	33	9	3	1	1		284
1951	%		17·6	25·0	40·8	11·6	3·2	1·1	0·4	0·4		
	Year-class	1950	1949	1948	1947	1946	1945	1944	1943	1942		
	No.	1	17	122	189	189	49	6	4			577
1952	%	0·1	2·9	21·1	32·8	32·8	8·7	1·0	0·7			
	Year-class	1951	1950	1949	1948	1947	1946	1945	1944			

APPENDIX TABLE 4

AGE-COMPOSITION OF PLAICE, RATTRAY HEAD–RED HEAD
ABERDEEN BAY

Series 1. "Goldseeker"—"Explorer", 9–20 fm
(Note: Nos. to nearest unit; % based on totals caught)

Year of sampling	Age-group	I	II	III	IV	V	VI	VII	VIII	IX	X+	Total per hour	Total Caught
	No. per hr	26	14	27	3	1	+	+	+	+	+	71	1291
1921	%	36·6	19·1	38·1	4·2	1·0	0·5	0·1	0·1	0·1	0·2		
	Year-class	1920	1919	1918	1917	1916	1915	1914	1913	1912	1911—		
	No. per hr	5	13	6	4	1	1	+	+			30	292
1922	%	16·4	45·6	20·6	13·0	1·7	1·7	0·7	0·3				
	Year-class	1921	1920	1919	1918	1917	1916	1915	1914				
	No. per hr	2	14	10	2	1	+	—	+			29	344
1923	%	6·2	48·2	35·5	6·8	2·4	0·6	—	0·3				
	Year-class	1922	1921	1920	1919	1918	1917	1916	1915				
	No. per hr	4	10	34	13	4	—	—	1	1		67	258
1924	%	5·4	14·7	52·7	20·2	5·4	—	—	0·8	0·8			
	Year-class	1923	1922	1921	1920	1919	1918	1917	1916	1915			
	No. per hr	12	508	5	1							526	3154
1925	%	2·2	96·6	1·0	0·3								
	Year-class	1924	1923	1922	1921								
	No. per hr	—	+	42	1	+	—	+				43	175
1926	%	—	1·1	96·0	1·7	0·6	—	0·6					
	Year-class	1925	1924	1923	1922	1921	1920	1919					
	No. per hr	+	3	3	13	+						19	319
1927	%	0·6	16·9	13·5	67·1	1·9							
	Year-class	1926	1925	1924	1923	1922							
	No. per hr	+	13	19	1	2						35	425
1928	%	0·9	37·9	53·4	3·1	4·7							
	Year-class	1927	1926	1925	1924	1923							
	No. per hr	2	30	9	3	—	—	+				44	263
1929	%	4·6	68·1	20·9	5·7	—	—	0·8					
	Year-class	1928	1927	1926	1925	1924	1923	1922					
	No. per hr	6	68	17	7	+						98	985
1930	%	6·3	69·0	17·7	6·9	0·1							
	Year-class	1929	1928	1927	1926	1925							
	No. per hr	155	23	1								179	358
1936	%	86·6	12·9	0·6									
	Year-class	1935	1934	1933									

APPENDIX TABLE 5

AGE-COMPOSITION OF PLAICE, RATTRAY HEAD–RED HEAD
ABERDEEN BAY

Series 2. "Enid"—"Kathleen", 2–10 fm
(Note: Nos. to nearest units; % calculated on total caught)

Year of sampling	Age-group	I	II	III	IV	V	VI	Total per hour	Total Caught
	No. per hr	30	25	9	4	1		69	2913
1931	%	43·3	35·8	13·7	6·4	0·7			
	Year-class	1930	1929	1928	1927	1926			
	No. per hr	208	23	2	1	+		234	3,333
1932	%	89·0	9·7	1·0	0·2	+			
	Year-class	1931	1930	1929	1928	1927			
	No. per hr	8	142	6	1	—		157	1,890
1933	%	5·3	90·7	3·5	0·3	—			
	Year-class	1932	1931	1930	1929	1928			
	No. per hr	122	10	13	1	+		146	4,054
1934	%	83·2	6·7	9·1	0·8	0·2			
	Year-class	1933	1932	1931	1930	1929			
	No. per hr	288	54	1	1	+		344	4,864
1935	%	83·8	15·6	0·3	0·1	+			
	Year-class	1934	1933	1932	1931	1930			
1936		no observations—see Appendix Table 4							
	No. per hr	13	92	2	1			108	935
1937	%	12·1	86·0	1·4	0·5				
	Year-class	1936	1935	1934	1933				
	No. per hr	118	47	26	1			192	1,251
1938	%	61·6	24·3	13·7	0·4				
	Year-class	1937	1936	1935	1934				
	No. per hr	29	94	8	3	+		134	3,751
1939	%	21·9	70·5	5·4	1·9	0·2			
	Year-class	1938	1937	1936	1935	1934			
1940–47		no observations							
	No. per hr	101	226	13	3	+		343	3,126
1948	%	29·3	65·9	3·9	0·8	+			
	Year-class	1947	1946	1945	1944	1943			
	No. per hr	460	28	14	2	1		505	1,009
1949	%	91·1	5·5	2·8	0·4	0·2			
	Year-class	1948	1947	1946	1945	1944			
	No. per hr	10	82	12	3	1		108	1,548
1950	%	8·9	76·4	11·4	2·8	0·5			
	Year-class	1949	1948	1947	1946	1945			
	No. per hr	317	35	121	3	2	+	478	20,887
1951	%	66·4	7·3	25·3	0·6	0·4	+		
	Year-class	1950	1949	1948	1947	1946	1945		
	No. per hr	106	222	19	10	1	1	359	5,761
1952	%	29·7	62·1	5·2	2·7	0·1	0·1		
	Year-class	1951	1950	1949	1948	1947	1946		

APPENDIX TABLE 6

AGE-COMPOSITION OF PLAICE, RATTRAY HEAD–RED HEAD
OFFSHORE GROUNDS 20–50 fm

Series 1. "Goldseeker"—"Explorer"

Year of sampling	Age-group	I	II	III	IV	V	VI	VII	VIII	IX	X+	Total
	No. per hr	30	40	120	23	3	3	1	—	—	4	224
1921	%	13·4	17·9	53·6	10·3	1·3	1·3	0·5	—	—	1·8	
	Year-class	1920	1919	1918	1917	1916	1915	1914	—	—	1911	
	No. per hr	—	1	3	7	3	—	—	1	1	2	18
1922	%	—	5·6	16·6	38·9	16·6	—	—	5·6	5·6	11·1	
	Year-class	1921	1920	1919	1918	1917	1916	1915	1914	1913	1912	
	No. per hr	—	—	55	41	35	3	1	—	1		136
1926	%	—	—	40·4	30·2	25·7	2·2	0·7	—	0·7		
	Year-class	1925	1924	1923	1922	1921	1920	1919	1918	1917		
	No. per hr		4	6	10	2	—	—	2			24
1931	%		16·7	25·0	41·7	8·4	—	—	8·4			
	Year-class	1930	1929	1928	1927	1926	1925	1924	1923			
	No. per hr	30	22	22	12	4	—	—	2			92
1934	%	32·6	23·9	23·9	13·0	4·4	—	—	2·2			
	Year-class	1933	1932	1931	1930	1929	1928	1927	1926			
	No. per hr	—	26	20	4	2	2					54
1937	%	—	48·2	37·0	7·4	3·7	3·7					
	Year-class	1936	1935	1934	1933	1932	1931					
	No. per hr	—	2	9	7	21	5	2	—	2	1	49
1951	%	—	4·1	18·5	14·3	42·8	10·2	4·1	—	4·1	2·0	
	Year-class	1950	1949	1948	1947	1946	1945	1944	1943	1942	1941	
	No. per hr	—	9	8	29	9	12	—	—	—	1	68
1952	%	—	13·2	11·7	42·6	13·2	17·7	—	—	—	1·5	
	Year-class	1951	1950	1949	1948	1947	1946	1945	1944	1943	1942	

APPENDIX TABLE 7

AGE-COMPOSITION OF PLAICE, RED HEAD–BABBET NESS
ST ANDREWS BAY

Series 1. "Goldseeker"—"Explorer", 6–11 fm

Year of sampling	Age-group	I	II	III	IV	V	Total per hour	Total Caught
	No. per hr	730	80	5			815	2,598
1922	%	89·6	9·8	0·6				
	Year-class	1921	1920	1919				
	No. per hr	385	1,692	34	+		2,111	15,233
1923	%	18·2	80·1	1·6	0·1			
	Year-class	1922	1921	1920	1919			
	No. per hr	151	811	269	7	1	1,239	2,475
1924	%	12·2	65·5	21·7	0·6	0·1		
	Year-class	1923	1922	1921	1920	1919		
	No. per hr	744	6,135	1,740	4		8,623	8,623
1925	%	8·6	71·2	20·2	+			
	Year-class	1924	1923	1922	1921			
	No. per hr	200	498	596	47	1	1,342	2,818
1926	%	14·9	37·1	44·4	3·5	0·1		
	Year-class	1925	1924	1923	1922	1921		
	No. per hr	479	1,670	41	10	1	2,201	12,331
1927	%	21·8	75·9	1·9	0·5	+		
	Year-class	1926	1925	1924	1923	1922		
	No. per hr	665	1,161	1,895	8	2	3,731	14,372
1928	%	17·8	31·1	50·8	0·2	+		
	Year-class	1927	1926	1925	1924	1923		
	No. per hr	82	748	384	261	1	1,476	8,056
1929	%	5·5	50·7	26·0	17·7	+		
	Year-class	1928	1927	1926	1925	1924		
	No. per hr	140	82	1,109	181	32	1,544	11,580
1930	%	9·0	5·3	71·6	11·7	2·1		
	Year-class	1929	1928	1927	1926	1925		
	No. per hr	110	155	43	1		309	922
1936	%	35·6	50·2	13·9	0·3			
	Year-class	1935	1934	1933	1932			

APPENDIX TABLE 8

AGE-COMPOSITION OF PLAICE, RED HEAD–BABBET NESS
ST. ANDREWS BAY

Series 2. "Enid"—"Kathleen", 2–11 fm

Year of sampling	Age-group	I	II	III	IV	V	VI	Total per hour	Total Caught
	No. per hr	57	217	119	655	4		1,052	5,163
1931	%	5·4	20·6	11·3	62·3	0·4			
	Year-class	1930	1929	1928	1927	1926			
	No. per hr	171	42	30	2	5	+	250	2,663
1932	%	68·2	16·9	12·1	0·7	2·0	0·1		
	Year-class	1931	1930	1929	1928	1927	1926		
	No. per hr	244	474	32	7	1		758	3,819
1933	%	30·6	59·5	8·0	1·6	0·1			
	Year-class	1932	1931	1930	1929	1928			
	No. per hr	442	130	51	1			634	7,505
1934	%	70·8	20·9	8·1	0·2				
	Year-class	1933	1932	1931	1930				
	No. per hr	94	204	12	1			311	2,857
1935	%	30·2	65·8	3·8	0·2				
	Year-class	1934	1933	1932	1931				
1936		no observations—see Appendix Table 7							
	No. per hr	21	200	10	1			232	959
1937	%	8·9	86·4	4·3	0·4				
	Year-class	1936	1935	1934	1933				
	No. per hr	17	31	80	1	1		130	2,508
1938	%	13·3	23·9	61·4	1·0	0·4			
	Year-class	1937	1936	1935	1934	1933			
	No. per hr	90	21	9	3			123	486
1939	%	73·3	17·2	7·3	0·2				
	Year-class	1938	1937	1936	1935				
1940–46		no observations							
	No. per hr	217	524	5				746	3,032
1947	%	29·0	70·3	0·7					
	Year-class	1946	1945	1944					
	No. per hr	—	122	29	1			152	603
1948	%	—	80·8	18·8	0·3				
	Year-class	1947	1946	1945	1944				
	No. per hr	29	63	368	11			471	940
1949	%	6·1	13·4	78·0	2·2				
	Year-class	1948	1947	1946	1945				
	No. per hr	94	56	38	166	3		357	1,859
1950	%	26·3	15·7	10·6	46·6	0·7			
	Year-class	1949	1948	1947	1946	1945			
	No. per hr	154	230	76	19	44	1	524	2,261
1951	%	29·4	43·9	14·5	3·6	8·5	0·1		
	Year-class	1950	1949	1948	1947	1946	1945		
	No. per hr	54	80	54	6	1		195	962
1952	%	27·9	41·0	27·6	2·9	0·7			
	Year-class	1951	1950	1949	1948	1947			

APPENDIX TABLE 9

AGE-COMPOSITION OF PLAICE, FIRTH OF FORTH

Series 1. "Goldseeker"—"Explorer", 10–26 fm, 1920–30, 1936
and Series 2. "Enid"—"Kathleen", 11–26 fm, 1948–52

(Note: Nos. to nearest unit; % calculated on total caught)

Year of sampling	Age-group	I	II	III	IV	V	VI	VII	VIII	IX	X+	Total per hour	Total Caught
	No. per hr	1	7	3	2	2	2	1	+	+	1	19	271
1920	%	6·3	37·1	14·9	13·7	10·3	9·7	4·0	0·6	0·6	2·9		
	Year-class	1919	1918	1917	1916	1915	1914	1913	1912	1911	1910		
1921		too few fish											8
	No. per hr	1	19	25	11	3	1	—	1	—	2	63	123
1922	%	1·6	30·1	40·7	17·1	4·9	1·6	—	1·6		2·4		
	Year-class	1921	1920	1919	1918	1917	1916	1915	1914	1913	1912—		
	No. per hr	—	3	7	14	4	1	1	+	+	1	31	372
1923	%	—	11·0	21·5	44·6	12·9	3·2	2·4	1·3	1·3	1·6		
	Year-class	1922	1921	1920	1919	1918	1917	1916	1915	1914	1913—		
	No. per hr		+	4	1	1	+			+	+	6	42
1924	%		3·3	53·3	16·7	16·7	3·3			3·3	3·3		
	Year-class	1923	1922	1921	1920	1919	1918	1917	1916	1915	1914—		
	No. per hr	—	5	30	26	4	2	1	+	+	+	68	763
1925	%	—	7·2	44·5	38·6	6·1	2·3	0·9	0·1	0·1	0·3		
	Year-class	1924	1923	1922	1921	1920	1919	1918	1917	1916	1915—		
	No. per hr			4	3	3	1	—	+	+	1	12	84
1926	%			31·8	22·7	25·0	8·0	—	3·4	1·1	8·0		
	Year-class	1925	1924	1923	1922	1921	1920	1919	1918	1917	1916—		
	No. per hr	2	23	6	30	9	2	1	1	+	1	75	2,100
1927	%	2·0	31·0	8·5	40·8	12·7	2·5	0·9	0·7	0·1	0·7		
	Year-class	1926	1925	1924	1923	1922	1921	1920	1919	1918	1917—		
	No. per hr	2	36	47	4	8	3	1	1	+	1	103	2,862
1928	%	2·1	35·2	46·6	3·9	7·4	2·7	0·9	0·5	0·4	0·5		
	Year-class	1927	1926	1925	1924	1923	1922	1921	1920	1919	1918—		
	No. per hr	+	12	40	17	3	2	1	+	—	+	75	1,284
1929	%	0·1	14·2	48·0	31·9	3·0	1·8	0·8	0·1	—	0·1		
	Year-class	1928	1927	1926	1925	1924	1923	1922	1921	1920	1919—		
	No. per hr	+	6	31	12	6	+	2	+	1	1	59	971
1930	%	0·4	10·2	51·3	20·6	10·1	0·6	3·4	0·7	1·1	1·7		
	Year-class	1929	1928	1927	1926	1925	1924	1923	1922	1921	1920—		
	No. per hr	—	7	8	5	2						22	22
1936	%	—	31·8	36·4	22·7	9·1							
	Year-class	1935	1934	1933	1932	1931							
	No. per hr	—	+	2	1	2	1	+				6	34
1948	%	—	6·2	34·3	21·8	24·9	9·3	3·1					
	Year-class	1947	1946	1945	1944	1943	1942	1941					
1949		no observations											
	No. per hr	—	3	4	7	1	+	+				15	215
1950	%	—	16·1	28·9	48·2	5·8	0·3	0·6					
	Year-class	1949	1948	1947	1946	1945	1944	1943					
	No. per hr	2	22	18	4	3	+	+				49	774
1951	%	4·0	45·9	36·1	7·2	6·5	0·2	0·2					
	Year-class	1950	1949	1948	1947	1946	1945	1944					
	No. per hr	+	3	13	6	1	+					23	434
1952	%	0·6	14·6	56·0	24·8	2·2	1·7						
	Year-class	1951	1950	1949	1948	1947	1946						

APPENDIX TABLE 10

AGE-COMPOSITION OF PLAICE, FIRTH OF FORTH

Series 2. "Enid"—"Kathleen", 2–10 fm
(Note: Nos. to nearest unit; % calculated on total caught)

Year of sampling	Age-group	I	II	III	IV	V	VI	VII+	Total per hour	Total Caught
	No. per hr	109	44	46	85	13	7	1	305	2,972
1931	%	35·7	14·4	14·9	28·0	4·3	2·3	0·3		
	Year-class	1930	1929	1928	1927	1926	1925	1924		
	No. per hr	83	30	10	3	2	+	+	128	2,928
1932	%	64·2	23·5	7·8	2·6	1·4	0·3	0·1		
	Year-class	1931	1930	1929	1928	1927	1926	1925		
	No. per hr	141	136	11	3	1	+	+	292	3,705
1933	%	44·1	42·7	3·5	0·9	0·3	+	0·1		
	Year-class	1932	1931	1930	1929	1928	1927	1926		
	No. per hr	189	175	57	7	1			429	5,005
1934	%	44·0	40·9	13·3	1·6	0·2				
	Year-class	1933	1932	1931	1930	1929				
	No. per hr	81	92	21	4	+	+		198	2,396
1935	%	40·8	46·6	10·5	1·8	0·2	+			
	Year-class	1934	1933	1932	1931	1930	1929			
1936		no observations—see series 1, Appendix Table 9								
	No. per hr	21	55	4	2	+	+		82	830
1937	%	25·3	66·7	5·2	2·4	0·1	0·1			
	Year-class	1936	1935	1934	1933	1932	1931			
	No. per hr	7	17	20	5	1	—	+	50	979
1938	%	14·1	34·1	39·3	9·7	2·6	—	0·2		
	Year-class	1937	1936	1935	1934	1933	1932	1931		
	No. per hr	50	38	18	12	2	+	+	120	628
1939	%	41·9	31·3	14·9	9·8	1·7	0·1	0·3		
	Year-class	1938	1937	1936	1935	1934	1933	1932		
1940–47		no observations								
	No. per hr	3	149	34	12	1			199	808
1948	%	1·6	74·7	17·2	6·0	0·6				
	Year-class	1947	1946	1945	1944	1943				
	No. per hr	60	31	53	4				148	148
1949	%	40·5	20·9	35·8	2·7					
	Year-class	1948	1947	1946	1945					
	No. per hr	54	53	14	9	1	+		131	1,883
1950	%	41·2	40·4	10·5	10·0	0·7	0·1			
	Year-class	1949	1948	1947	1946	1945	1944			
	No. per hr	147	151	25	6	3			332	3,904
1951	%	44·4	45·5	7·4	1·9	0·8				
	Year-class	1950	1949	1948	1947	1946				
	No. per hr	11	30	24	1	+			66	730
1952	%	15·8	45·0	36·3	2·4	0·4				
	Year-class	1951	1950	1949	1948	1947				

APPENDIX TABLE 11

AGE-COMPOSITION OF PLAICE, BROAD BAY

Year of sampling	Age-group	I	II	III	IV	V	VI	VII+	Total
	No.	2	172	34	2				210
1924	%	1·0	**81·9**	16·2	1·0				
	Year-class	1923	1922	1921	1920				
1925		no records							
	No.	46	517	175	19	1			758
1926	%	6·1	**68·2**	23·1	2·5	0·1			
	Year-class	1925	1924	1923	1922	1921			
	No.	7	269	662	71	8	1		1,018
1927	%	0·7	26·4	**65·0**	7·0	0·8	0·1		
	Year-class	1926	1925	1924	1923	1922	1921		
1928		no records							
	No.	6	44	73	49	11	1		184
1929	%	3·3	**23·9**	39.6	26·7	6·0	0·5		
	Year-class	1928	1927	1926	1925	1924	1923		
	No.	32	358	168	15	4	2	2	581
1930	%	5·5	**61·6**	29·0	2·6	0·7	0·3	0·3	
	Year-class	1929	1928	1927	1926	1925	1924	1923	
1931		no records							
	No.	32	176	64	6				278
1932	%	11·5	**63·3**	23·0	2·2				
	Year-class	1931	1930	1929	1928				
	No.	178	462	16	4	4	—	2	666
1933	%	26·7	**69·4**	2·4	0·6	0·6	—	0·3	
	Year-class	1932	1931	1930	1929	1928	1927	1926+	
	No.	164	204	144	30	4			546
1934	%	30·0	**37·4**	26·4	5·5	0·7			
	Year-class	1933	1932	1931	1930	1929			
	No.	34	576	310	140	92	2	12	1,166
1935	%	2·9	**49·4**	26·6	12·0	7·8	0·2	1·0	
	Year-class	1934	1933	1932	1931	1930	1929	1928	
	No.	226	216	304	32	12	10	2	802
1936	%	28·2	27·0	**37·9**	4·0	1·5	1·2	0·2	
	Year-class	1935	1934	1933	1932	1931	1930	1929+	
	No.	242	1,180	168	30	12	2	4	1,638
1937	%	14·9	**72·0**	10·3	11·8	0·7	0·1	0·2	
	Year-class	1936	1935	1934	1933	1932	1931	1930+	
	No.	—	36	90	4				130
1938	%	—	27·7	**69·2**	3·1				
	Year-class	1937	1936	1935	1934				
	No.	—	28	732	948	148	78	114	2,048
1939	%	—	1·3	35·7	**46·3**	7·2	4·0	5·6	
	Year-class	1938	1937	1936	1935	1934	1933	1932+	
1940–49		no records							
	No.	45	145	87	85	71	22	14	470
1950	%	9·4	**30·9**	18·5	18·1	15·1	4·7	3·0	
	Year-class	1949	1948	1947	1946	1945	1944	1943+	
	No.	9	53	74	27	36	29	13	241
1951	%	3·8	22·0	**30·7**	11·2	**14·9**	12·0	5·4	
	Year-class	1950	1949	1948	1947	1946	1945	1944+	
	No.	—	73	26	15	5	5	8	132
1952	%	—	**55·3**	19·7	11·4	3·8	3·8	6·0	
	Year-class	1951	1950	1949	1948	1947	1946	1945	

APPENDIX TABLE 12

AGE-COMPOSITION OF PLAICE, SHETLAND

Year of sampling	Age-group	I	II	III	IV	V	VI	VII+	Total
	No.	—	—	13	24	3	1	1	42
1923	%	—	—	31·0	**57·1**	7·1	2·4	2·4	
	Year-class	1922	1921	1920	1919	1918	1917	1916+	
1924–28		no records							
	No.	—	1	3	15	4	6	2	31
1929	%	—	3·2	9·7	**48·4**	12·9	**19·4**	6·4	
	Year-class	1928	1927	1926	1925	1924	1923	1922+	
1930		no records							
	No.	—	—	20	11	8	2	1	42
1931	%	—	—	**47·6**	26·2	19·0	4·8	2·4	
	Year-class	1930	1929	1928	1927	1926	1925	1924+	
	No.	—	3	15	39	10	2	3	72
1932	%	—	4·1	20·7	**54·8**	13·8	2·7	4·0	
	Year-class	1931	1930	1929	1928	1927	1926	1925	
	No.	—	—	9	18	9	4	1	41
1933	%	—	—	21·9	**43·9**	21·9	9·8	2·4	
	Year-class	1932	1931	1930	1929	1928	1927	1926+	
	No.	—	2	13	31	21	7	3	77
1934	%		2·6	16·9	**40·2**	27·3	9·1	3·9	
	Year-class	1933	1932	1931	1930	1929	1928	1927+	
	No.	—	4	10	6	2	3	1	26
1935	%	—	15·4	**38·5**	23·1	7·7	11·5	3·8	
	Year-class	1934	1933	1932	1931	1930	1929	1928+	
	No.	—	4	20	12	6	—	1	43
1936	%	—	9·3	**46·5**	27·9	19·9	—	2·5	
	Year-class	1935	1934	1933	1932	1931	1930	1929	
1937–38		no records							
	No.	—	—	10	8	7	—	2	27
1939	%	—	—	**37·0**	29·6	25·9	—	7·4	
	Year-class	1938	1937	1936	1935	1934	1933	1932+	
1940–45		no records							
	No.	—	11	76	62	47	22	27	245
1946	%	—	4·5	**31·0**	25·3	19·2	9·0	11·0	
	Year-class	1945	1944	1943	1942	1941	1940	1939+	
	No.	—	3	13	11	3	4	5	39
1947	%	—	7·7	**33·3**	28·2	7·7	10·2	12·8	
	Year-class	1946	1945	1944	1943	1942	1941	1940+	
1948		no records							
	No.	—	1	18	24	30	9	17	99
1949	%	—	1·0	18·1	24·2	**30·3**	9·1	17·3	
	Year-class	1948	1947	1946	1945	1944	1943	1942	

APPENDIX TABLE 13

AGE-COMPOSITION OF PLAICE, ORKNEY

Year of sampling	Age-group	I	II	III	IV	V	VI	VII+	Total
			(a) "Explorer"—"Scotia"						
	No.	1	24	20	14	2			61
1932	%	1·6	**39·3**	32·8	22·9	3·9			
	Year-class	1931	1930	1929	1928	1927			
	No.	—	13	22	5	—	—	1	41
1933	%	—	31·7	**53·7**	12·2	—	—	2·4	
	Year-class	1932	1931	1930	1929	1928	1927	1926+	
	No.	—	36	46	25	4			111
1934	%	—	32·4	**41·4**	22·5	3·6			
	Year-class	1933	1932	1931	1930	1929			
	No.	—	6	9	9	1	1	3	29
1935	%	—	20·7	**31·0**	**31·0**	3·4	3·4	10·4	
	Year-class	1934	1933	1932	1931	1930	1929	1928+	
	No.	1	20	29	1	—	1		52
1936	%	1·9	38·5	**55·8**	1·9	—	1·9		
	Year-class	1935	1934	1933	1932	1931	1930		
	No.		19	29	25	1			74
1937	%		25·7	**39·2**	33·8	1·3			
	Year-class	1936	1935	1934	1933	1932			
	No.		3	6	15	8	—	1	33
1938	%		9·1	18·2	**45·5**	24·2	—	3·0	
	Year-class	1937	1936	1935	1934	1933	1932	1931	
			(b) "Kathleen" (O–group omitted)						
	No.	16	19	19	3	1			58
1939	%	27·5	**32·8**	**32·8**	5·2	1·7			
	Year-class	1938	1937	1936	1935	1934			
1940–47		no records							
	No.	175	605	227	65	19	6	1	1,098
1948	%	15·9	**55·1**	20·7	5·9	1·7	0·5	0·1	
	Year-class	1947	1946	1945	1944	1943	1942	1941	
1949–50		no records							
	No.	237	331	21	1	2			592
1951	%	40·0	**55·9**	3·5	0·2	0·3			
	Year-class	1950	1949	1948	1947	1946			
	No.	294	690	52	—	2			1,038
1952	%	28·3	**66·5**	5·1	—	0·1			
	Year-class	1951	1950	1949	1948	1947			

APPENDIX TABLE 14

AGE-COMPOSITION OF PLAICE, NORTH COAST OF SCOTLAND

Year of sampling	Age-group	I	II	III	IV	V	VI	VII+	Total
			(a) "Explorer"—"Scotia"						
	No.	—	2	18	14	5	4	3	46
1920	%	—	4·3	**39·1**	30·4	10·9	8·7	6·5	
	Year-class	1919	1918	1917	1916	1915	1914	1913+	
1921–23		no records							
	No.	2	24	50	13	4	—	1	94
1924	%	2·1	25·5	**53·2**	13·8	4·3	—	1·1	
	Year-class	1923	1922	1921	1920	1919	1918	1917+	
1925		no records							
	No.	1	6	14	7	2			30
1926	%	3·3	20·0	**46·7**	23·3	6·7			
	Year-class	1925	1924	1923	1922	1921			
1927–35		no records							
	No.	—	5	13	5	4	5	4	36
1936	%	—	13·9	**36·1**	13·9	11·1	13·9	11·1	
	Year-class	1935	1934	1933	1932	1931	1930	1929+	
	No.	1	14	20	11	4	5	1	56
1937	%	1·8	25·0	**35·7**	19·6	7·1	9·0	1·8	
	Year-class	1936	1935	1934	1933	1932	1931	1930+	
			(b) "Kathleen" (excluding O-group)						
	No.	96	86	9	4	1	1		197
1937	%	**48·7**	**43·7**	4·6	2·0	0·5	0·5		
	Year-class	1936	1935	1934	1933	1932	1931		
	No.	17	62	64	7	2	1		153
1938	%	11·1	**40·5**	**41·8**	4·6	1·3	0·7		
	Year-class	1937	1936	1935	1934	1933	1932		
	No.	40	33	42	27	3	1		146
1939	%	27·4	22·6	**28·8**	18·5	2·0	0·7		
	Year-class	1938	1937	1936	1935	1934	1933		
1940–50		no records							
	No.	1,699	1,280	145	46	7			3,177
1951	%	**53·5**	40·3	4·6	1·4	0·2			
	Year-class	1950	1949	1948	1947	1946			
	No.	117	124	79	(Dunnet Bay only)				320
1952	%	36·6	**38·7**	24·7					
	Year-class	1951	1950	1949					

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